ODICAL Kyoto Univ. Faculty of Agri. Memoirs
-3
LIBRARY
FISH & WILDLIFE SERVICE
PACIFIC OCEANIC FISHERY
INVESTIGATIONS
FEB 12 1954
66-3

MEMOIRS
OF THE
COLLEGE OF AGRICULTURE
KYOTO UNIVERSITY

No. 66 March 1953

(Fisheries Series No. 3)

1. On the Configuration and Distribution of Tension of a Rope in a Uniform Stream.
By Tasae KAWAKAMI and Humio TUBOTA

2. The Drag Acting on a Net in a Uniform Current, II
By Hiroshi FUJITA

3. Revision of Japanese Serranid Fish, referable to the Genus *Acropoma*
By Kiyomatsu MATSUBARA

4. Studies on the Biochemical Activities of Marine Bacteria, II On the Properties of Agar-digesting Enzyme of *Vibrio purpureus*
By Hajime KADOTA

5. The Phytoplankton of Lake Mikata
By Yuichi YONEDA

6. Marine Cyanophyceae from Wakasa Bay (1)
By Isamu UMEZAKI

PUBLISHED BY THE KYOTO UNIVERSITY
KYOTO, JAPAN

MEMOIRS OF THE COLLEGE OF AGRICULTURE

The Memoirs of the College of Agriculture, Kyoto University are serials published indeterminately by the Kyoto University and they purport to present research contributions by the members and associates of the seven Institutes included in the College: Agriculture, Forestry, Agricultural Chemistry, Agricultural Biology, Agricultural Engineering, Agricultural Economics and Fisheries. The Memoirs are numbered serially and classified into different series. Copies of the Memoirs will be sent gratuitously and preferably on an exchange basis to the institutions and libraries on our list. They may be obtained also through the sales agent, Maruzen Co., Ltd., Tokyo, Japan. A complete list of the Memoirs is appended to each Memoir.

All communications regarding the Memoirs and publications sent in exchange should be addressed to the Library, College of Agriculture, Kyoto University, Kyoto, Japan.

PUBLICATION COMMITTEE

Professor Fuyuo KAGAWA	Dean of the College, Chairman of Committee
Professor Yotaro TSUKAMOTO	Agriculture
Professor Ayaakira OKAZAKI	Forestry
Professor Azuma OKUDA	Agricultural Chemistry
Professor Shunichiro IMAMURA	Agricultural Biology
Professor Toyoichi TAKATSUKI	Agricultural Engineering
Professor Sukekata KASHIWA	Agricultural Economics
Professor Wataru SHIMIDU	Fisheries
Professor Shigeyasu AKAI	Managing Editor

On the Configuration and Distribution of Tension of a Rope in a Uniform Stream.

By

Tasae KWAKAMI and Humio TUBOTA*

With 5 Tables and 7 Text-figures

I. Introduction

When a flexible rope supported by both ends at two fixed points is subjected freely to a uniform current of water, an equilibrium configuration and distribution of tension will appear due to the relative velocity of water as well as to the apparent gravity of rope in the water. On account of its importance in the theory of operation of various gears for navigation and fishery, many investigations on this subject have been carried out, but we still have some questions. This paper deals with some considerations and experiments on this problem.

In the course of this study, the authors had an opportunity of reading a series of literatures on a similar subject as treated here published by The David W. Taylor Model Basin, U. S. Navy, by courtesy of Assist. Prof. H. FUJITA to whom the authors are much indebted. Before going further, the authors wish to express their hearty thanks to Miss E. ARAKI who carried out some of the computations requied and also to the crew of the experimental fishing boat Ryokuyô Maru for their assistance in managing the boat.

The expenses for executing this study were partly defrayed by the research fund from the Ministry of Education.

II. Mathematical Considerations

As to the hydrodynamic force of relative velocity of water acting on unit length of linear part of a rope, we have two assumptions; TAUTI[1] assumed in his paper on the resistance of a piece of fishing net that the resisting force is directed normal to the central axis of the arm of net and lying in the plane including directions of the arm and the stream and that its magnitude R_θ is proportional to the sine of the angle, θ, between the axis of the arm and the direction of the flow, i. e.

$$R_\theta = R\sin\theta. \tag{1}$$

However, the frictional force which acts upon the rope in the direction parallel

* Laboratory of Applied Physics.

to its axis may not be neglected, especially when the rope is towed almost horizontally as is the case with warp of a trawl net. If we denote the frictional force acting on unit length of a rope when its axis coincides with the direction of flow by F, the tangential force F_θ when the rope is inclined with the angle θ against the stream will be represented from the same idea as above by the following formula:

$$F_\theta = F\cos\vartheta. \tag{2}$$

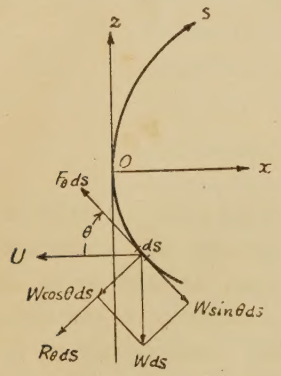


Fig. 1.

These assumptions expressed by the equations (1) and (2) will be cited as "the sine law" in the following.

In a rectangular coordinate (x, z), the origin O of which is fixed on a point of the rope, let z axis be directed vertically upwards and let x axis be parallel to the stream line, measured positive up-stream as shown in Fig. 1. Let the arc length along the rope measured from the origin O to any point P(x, z) on the rope be s, the tension of the rope at this point be T and the apparent weight of unit length of the rope in water be W, the equations of equilibrium can be written as

$$\frac{dT}{ds} = W\sin\theta - F\cos\vartheta, \tag{3}$$

$$T\frac{d\theta}{ds} = R\sin\theta + W\cos\vartheta, \tag{4}$$

where the angle θ is measured positive clockwise from the direction of current to the direction of increasing s as shown in the figure.

Now, the following dimensionless quantities:

$$\begin{aligned} &\tau = \frac{T}{T_0}, && \mu = \frac{W}{R}, && \nu = \frac{F}{R}, \\ &\sigma = \frac{R}{T_0}s, && \xi = \frac{R}{T_0}x, && \zeta = \frac{R}{T_0}z \end{aligned} \tag{5}$$

are introduced, where T_0 signifies the tension of the rope at the origin. The differential equations (3) and (4) may be integrated with the condition that

$$\sigma = 0 \quad (\xi = 0,\ \zeta = 0) \quad \text{for} \quad \theta = \frac{\pi}{2}$$

to give

$$\tau = (\sin\theta + \mu\cos\theta)^{-\frac{\mu^2+\nu}{\mu^2+1}} \exp\left[\frac{\mu(1-\nu)}{\mu^2+1}\left(\theta - \frac{\pi}{2}\right)\right], \tag{6}$$

$$\sigma = \int_{\frac{\pi}{2}}^{\theta} \frac{\tau}{\sin\theta + \mu\cos\theta}\, d\theta, \tag{7}$$

$$\xi = -\int_{\frac{\pi}{2}}^{\theta} \frac{\tau\cos\theta}{\sin\theta + \mu\cos\theta}\, d\theta, \tag{8}$$

$$\zeta = \int_{\frac{\pi}{2}}^{\theta} \frac{\tau\sin\theta}{\sin\theta + \mu\cos\theta}\, d\theta, \tag{9}$$

For a special case in which the apparent weight of the rope is negligible compared with the hydrodynamic force i. e. $\mu=0$, the equation (6) may be simplified to

$$\tau=\operatorname{cosec}^2\theta. \tag{10}$$

On the other hand, however, there is an opinion which is different from the above assumption as follows. Decompose the velocity vector, U, of the current into its normal component, U_N, and tangential component, U_T, with respect to the curve of rope, i. e.

$$U_N=U\sin\theta, \quad U_T=U\cos\theta$$

Then, if we consider that these normal and tangential components of the current act independently on the rope, R_θ may be represented as follows:

$$R_\theta=\frac{C_D}{2}\rho U_N^2 D=\frac{C_D}{2}\rho U^2 D\sin^2\theta=R\sin^2\theta,$$

where D is the diameter of the rope, ρ the density of water, and C_D the drag coefficient of a circular cylinder, taking the sense of the force into account, the above relation should be written as:

$$R_\theta=R\mid\sin\theta\mid\sin\theta. \tag{11}$$

As to F_θ, the similar consideration gives

$$F_\theta=F\mid\cos\theta\mid\cos\theta. \tag{12}$$

These assumptions will be cited as "the sine-square law" in the following. The equations of equilibrium based on these assumptions are

$$\frac{dT}{dS}=W\sin\theta-F\mid\cos\theta\mid\cos\theta, \tag{13}$$

$$T\frac{d\theta}{ds}=R\mid\sin\theta\mid\sin\theta+W\cos\theta, \tag{14}$$

the solution of which, with the same notations and the initial condition as above, takes the form:

$$\tau=\exp\int_{\frac{\pi}{2}}^{\theta}\frac{\mu\sin\theta-\nu\mid\cos\theta\mid\cos\theta}{\mid\sin\theta\mid\sin\theta+\mu\cos\theta}d\theta \tag{15}$$

$$\sigma=\int_{\frac{\pi}{2}}^{\theta}\frac{\tau}{\mid\sin\theta\mid\sin\theta+\mu\cos\theta}\,d\theta, \tag{16}$$

$$\xi=-\int_{\frac{\pi}{2}}^{\theta}\frac{\tau\sin\theta}{\mid\sin\theta\mid\sin\theta+\mu\cos\theta}\,d\theta, \tag{17}$$

$$\zeta=\int_{\frac{\pi}{2}}^{\theta}\frac{\tau\sin\theta}{\mid\sin\theta\mid\sin\theta+\mu\cos\theta}\,d\theta, \tag{18}$$

For a special case in which the apparent weight is negligible, the expressions can be simplified to

$$\tau=\exp\left[\frac{\sin 2\theta}{\mid\sin 2\theta\mid}\nu\left(\cot\theta+\theta-\frac{\pi}{2}\right)\right], \tag{19}$$

$$\sigma=\int_{\frac{\pi}{2}}^{\theta}\frac{\tau}{\mid\sin\theta\mid\sin\theta}\,d\theta, \tag{20}$$

$$\xi = -\int_{\frac{\pi}{2}}^{\theta} \frac{\tau \cos\theta}{|\sin\theta| \sin\theta} d\theta, \tag{21}$$

$$\zeta = \int_{\frac{\pi}{2}}^{\theta} \frac{\tau}{|\sin\theta|} d\theta, \tag{22}$$

This assumption of the sine-square law is very formal and conventional. It seems to hav a poor physical basis. Nevertheless, the fact that the normal force is proportional to the square of the sine of the angle θ has been roughly proven by experiment and supported by many hydrodynamists, As to the tangential force, however, we have little knowledge.

III. Experiment

It is obscure whether the hydrodynamic force acting upon ropes when they move in the water with velocities which frequently appear in ordinary operations of various fishing gears obeys the sine law or the sine-square law, and also whether the tangential force is negligible as compared with the normal force. A series of experiments has been undertaken to clarify these questions. A spherical lead sinker of different sizes as shown in Table 1 was towed from a motor-boat with a rope

Table 1. Lead sinker

No.	Diameter (in cm.)	Weight in water (in kg,)
1	9	1.2
2	9	4.3
3	10	5.8
4	13	11.1

Table 2. Rope

No.	Diameter D (in cm.)	Material
1	0.24	hcmp-palm
2	0.35	,,
3	0.42	,,
4	0.62	,,
5	1.05	coco
6	1.37	hemp-palm
7	1.86	manilla hemp

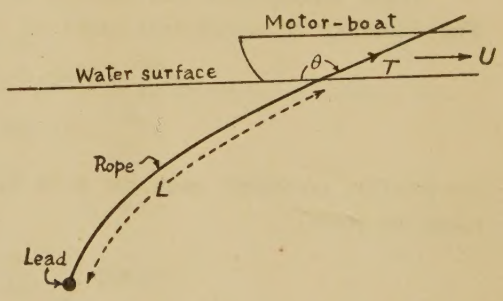


Fig 2. Schematical sketch of the experiment.

having various diameters D as indicated in Table 2. Fig. 2 gives a schematieal sketch of the general arrangement of the experiment. The speed U of the motor-bost was regulated by using a simple log of the PITOT tube type. In this experiment, the value of U was varied within the range from 150 to 300 cm./sec., so that the corresponding REYNOLDS number formed with the diameter of the rop amounted to the order of $(0.5 \sim 5.0) \times 10^4$, at which NEWTON's law of fluid resistance may hold. Therefore, if we assume that the drag coefficient of a circular cylinder is approximately equal to 1.1 and that the density of rope is equal to 1.3 g./cm^3., the value of μ is given by

$$\mu \fallingdotseq 500 \frac{D}{U^2}.$$

The maximum value of μ attained in these experiments is then calculated by substituting 150 cm./sec. for U and 1.86 cm. for D to give 0.04, which is considered to be negligibly small compared with unity. It is assumed that $\mu=0$ in the follwing. Then the equations (10) and (19) can be written in the forms:

$$\log T = \log T_0 - \nu \log \sin\theta \tag{23}$$

and

$$\log T = \log T_0 - \frac{\sin 2\theta}{|\sin 2\theta|}\,\nu\,(\cot\theta + \theta - \frac{\pi}{2}) \tag{24}$$

respectively. In Fig. 3, I shows an example of the relation between $\log T$ and $\log \sin\theta$ and II the relation between $\log T$ and $\cot\theta+\theta-\frac{\pi}{2}$, both of which appear to be sufficiently linear within the range of observational errors. But, examining all other data obtained by the present experiment, the plot I seems to have a slightly concave tendency upward as is shown by the dotted line in the figure. It is a note-worthy fact that the point corresponding to $L=0$ shows a sudden leap, which is considered to be due to the fact that the sinker is subjected to the wave-making resistance on account of the movement along the surface of sea-water.

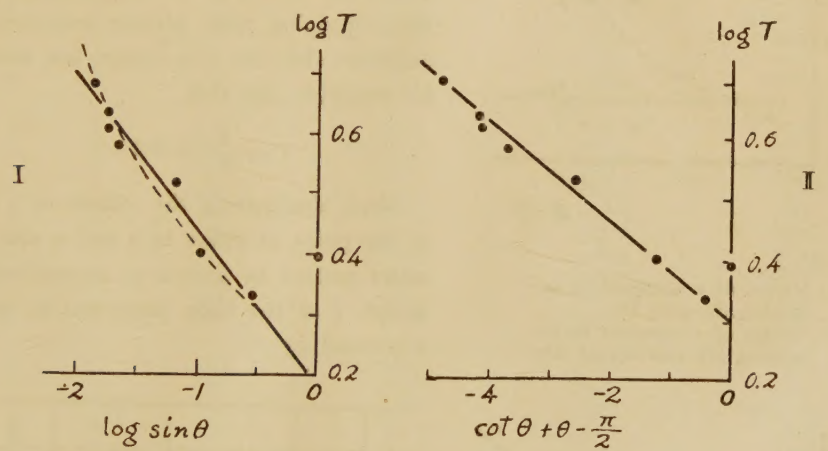


Fig. 3. I: Relation between $\log T_0$ and $\log \sin\theta$
II: Relation between $\log T_0$ and $\cot\theta+\theta-\frac{\pi}{2}$

Therefore, with omissson of this point, the values of ν and T_0 are computed respectively from the slope and intercept of the straight line. The results are summarized in Table 3, in which ν_{I} denotes the value obtained by assuming the sine law and ν_{II} the one obtained by assuming the sine-square law. The remarkable fact is that the values of ν_{I} show a considerable fluctuation over the range from 0.1 to 0,3, while ν_{II} shows a rather stable value ranging in a narrow interval from 0.06 to 0.13. In Fig.4, the values of ν thus obtained are plotted against the angle of inclication of rope at the water surface. It is seen that both values of ν coincide

Table 3.

Exp.	Rope	Sinker	U cm/sec.	$\theta-\frac{\pi}{2}$	Sine law		Sine-square law	
					ν_I	T_0 kg	ν_{II}	T_0 kg.
No. 1	No. 4	No. 1	170	81°	0.26	1.19	0.080	1.36
2	〃	〃	150	〃	0.39	1.21	.091	1.34
3	〃	〃	170	80	.28	1.23	.088	1.37
4	〃	〃	〃	79	.30	1.17	.098	1.30
5	〃	No. 2	180	64	.095	4.66	080	4.69
6	〃	〃	190	74	.105	4.82	·070	4.88
7	〃	〃	〃	75	.092	4.81	·054	4.87
8	No. 7	No. 4	350	81	.125	10.60	·060	12.20
9	6	3	300	82	.44	5.75	·114	7.50
10	3	2	255	75	.28	4.53	·130	4.86
11	2	1	267	83	.42	1.29	·111	1.61
12	3	2	〃	76	.30	4.57	·.127	5.10
13	1	1	〃	82	.40	1.39	.124	1.59

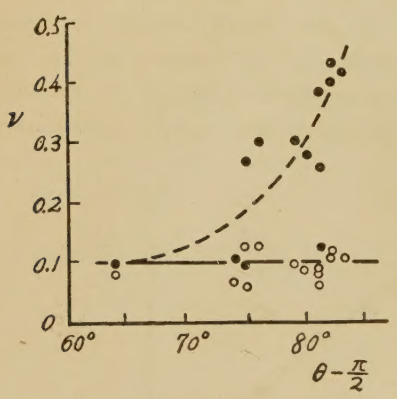


Fig. 4.
●: Values of ν obtained by assuming the sine law.
○: Values of ν obtained by assuming the sine-square law.

fairly well with each other for the inclinations near vertical, and that the values of ν_{II} show a fair constancy over a wide range of inclination, while the values of ν_I show a systematic increase with increasing inclination. Judging from various points, we may conclude that the sine-square law seems to be plausible and that

$$\nu \equiv \frac{F}{R} \fallingdotseq 0.10.$$

Next, designating the values of s and σ at the point of sinker by s and σ and at the water surface by s_s and σ_s respectively, the length L of the rope immersed in water is expressed by

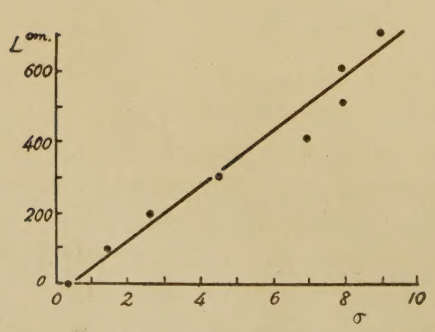


Fig. 5. Relation between the length of rope drawn out and the value of σ calculated by the eq. (20).

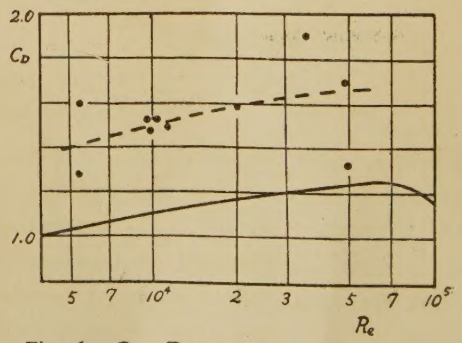


Fig. 6. ●: Drag coef. of a rope.
—: Drag coef. of a circular cylinder.

$$L=S-S_s=\frac{T_0}{R}(\sigma-\sigma_s). \qquad (25)$$

Since the numerical value of σ can be calculated by the equation (20) as a function

Table 4.

θ or $(\pi-\theta)$	τ	σ	ξ	$\pm\ \varsigma$
90°	1.0000000	0.00000	0.000000	0.00000
9	1.0000005	0.01746	0.000153	0.01745
8	1.0000017	3493	610	3491
7	49	5241	0.001373	5238
6	1.000011	6993	2442	6787
5	22	8749	3820	8738
4	38	0.10510	5509	0.10491
3	61	2278	7510	2248
2	91	4054	9828	4009
1	1.00013	5838	0.012466	5774
80	18	7633	15428	7543
9	24	9439	18719	9319
8	31	0.21256	22344	0.21100
7	40	3088	26308	2889
6	50	4936	30619	4684
5	61	6799	35285	6488
4	75	8680	40313	8301
3	90	0.30580	45710	0.30123
2	1.00103	2501	51486	1955
1	127	4444	57650	3797
70	149	6411	64216	5651
9	174	8404	71194	7518
8	201	0.40423	78598	9397
7	231	2473	86441	0.41290
6	264	4553	94737	3198
5	300	6667	0.103504	5122
4	340	8816	12760	7062
3	384	0.51004	22522	9019
2	431	3231	32807	0.50995
1	483	5501	43639	2990
60	539	7817	0.15504	5005
9	600	0.60181	6704	7402
8	666	2597	7967	9102
7	737	5069	9295	0.61186
6	814	7597	0.20691	3296
5	897	0.70190	2159	5432
4	987	2848	3703	7596
3	1.01084	5578	5326	9789
2	1188	8383	7033	0.72014
1	1299	0.81268	8830	4272
50	1420	4239	0.30720	6565
9	1549	7303	2710	8894
8	1688	0.90465	4805	0.81263
7	1837	3733	7013	3672
6	1997	7114	9340	6124
5	2169	1.0062	0.41795	8622
4	2354	0425	4387	0.91168
3	2553	0802	7125	3766
2	2766	1195	0.50019	6418
1	2996	1604	3083	9128
40	3242	2031	6328	1.0190

θ or $(\pi-\theta)$	τ	σ	ξ	$\pm\ \varsigma$
9	3508	2477	9770	474
8	3794	2944	.63424	764
7	4102	3433	7309	1.1062
6	4435	3948	.71444	368
5	4794	4489	5853	683
4	5182	5060	.80562	1.2006
3	5602	5664	5599	339
2	6057	6305	.90997	683
1	6551	6984	6793	1.3038
30	7089	1.7708	1.0303	406
9	7674	8481	0976	786
8	8314	9309	1704	1.4181
7	9014	2.0199	2493	592
6	9782	1158	3352	1.5020
5	1.10628	2197	4289	467
4	1562	3324	5316	935
3	2598	4556	6445	1.6425
2	3749	5906	7692	942
1	5036	7394	9076	1.7487
20	6483	9042	2.0619	1.8063
9	8117	3.0880	2352	677
8	9974	2945	4311	1.9332
7	1.22001	5283	6540	2.0034
6	4556	7953	9101	0792
5	7418	4.1035	3.2071	1615
4	1.30791	4633	5554	2515
3	4818	8892	9695	3508
2	9700	5.4013	4.4696	4615
1	1.45729	6.0290	5.0847	5865
10	53342	8165	8591	7297
9	63232	7.8331	6.8618	8971
8	76530	9.1942	8.2080	3.0975
7	95340	11.106	10.103	3462
6	2.23631	13.972	12.951	6687
5	70378	18.690	17.648	4.1171
4	3.59653	27.677	26.602	8125
3	5.79080	49.733	48.624	6.1241
2	15.0298	114.55	142.44	9.9607
1	263.397	3351.7	3356.1	32.953
0	∞	∞	∞	∞

of θ, we can plot the value of L against σ from the result of the experiments. An example of this plot is shown in Fig. 5, which indicates that the equation (25) holds pretty well. Thus the value of R may be estimated by using the slope of this straight line. On the other hand, the numerical value of T_o' have been obtained formerly, so that we can estimate the value o fdrag coeficient C_D.

The relation of the drag coefficient to the REYNOLDS number thus obtained is shown in Fig. 6, in which the heavy line shows the same relation for the case of an infinite circular cylinder which has been investigated by many authorities.

Although the accuracy of the present experiments is not so high, it can be seen from the figure that the value for ropes is larger than that for the circular cylinder.

IV. Numerical Computation

Numerical computations given by the equations (19), (20), (21) and (22) were carried out by hand with the use of a desk calculator for the case : $\mu=0$ and $\nu=0.1$. The calculation of τ offers no difficulty. σ, ξ and ζ were integrated numerically by using SIMPSON's one-third rule with interval of 5° for the range from 2° to 160°, while for the range from 160° to 179° or from 20° to 1° the interval was reduced to 1°. The results are compiled in Table 4.

V. Considerations on the value of ν

According to JEFERYS, TAYRLOR and EKMAN[2], the shearing stress F^* acting on a unit area of a plane by a parallel current velocity U of a fluid with the density ρ is given by $$F^*=k\rho U^2,$$ where k is a constant with a value of 0.020~0.025. Then if the numerical value of C_D in the case of rope is assumed to be equal to 1.4 as has been shown in this study, this gives $$R=\frac{1.4}{2}\rho U^2 D.$$ Thus we obtian $$\nu=\frac{F^*}{R}=\frac{k\pi}{0.7}=0.09\sim0.11,$$ which shows a good agreement with the experimental result.

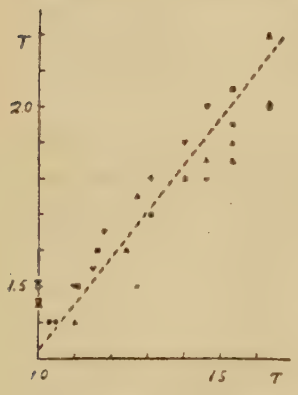


Fig. 7. Relation between T and τ. Different mareks represent the different experiments.

For caution's sake, with the rope No. 4 and sinker No, 1 (Exp. No. 1~4), the relation of the value of T observed to that of τ corresponding to the observed value of θ (Table. 4.) is plotted in Fig. 7 in which the dotted line represents the relation : $\frac{T}{T_0}=\tau$ with $T_0=1.32$. This vaule of T_0 shows an agreement with the mean value (=1.34) of T_0.

The tangential force F_θ being much smaller than the normal force, THEWS, LANDWEBER and their coworkers [3)~(7)] of the D. W. Taylor Model Basin have assumed in their investigations that F has a constant value, $\overline{F}$, over the whole range of θ. Their assumptions were based on the experiments of RELF aud POWELL. And PODE has carried out a series of comprehensive numerical computations with the cases that the value of $\frac{R}{F}$ $(\equiv f)$ is equal to 0.01, 0.02 and 0.03. From the point of view of the present author's assumption, these values of f are mean values of $\frac{R}{F}\cos^2\theta$ with respect to s. But, for the sake ofsimplicity the mean with respect to θ tentatively calculated as follows :

$$f=\frac{1}{\theta-\frac{\pi}{2}}\int_{\frac{\pi}{2}}^{\theta}\frac{R}{F}\cos^2\theta\, d\theta$$

$$= 0.5 + \frac{0.25}{\theta - \frac{\pi}{2}} \sin 2\theta$$

The relation of f to θ obtained from this formula indicates that it is reasonable to use values corresponding to the large values of f in the case of large inclination and vice versa.

Table 5.

	θ	$\gamma=0.1$	f		
			0.01	0.02	0.03
τ	10	1.53342	1.0584	1.1201	1.1855
	20	1.16483	1.0279	1.0565	1.0859
	40	1.03242	1.0120	1.0241	1.0364
	60	1.00539	1.0058	1.0116	1.0175
	80	1.00018	1.0018	1.0035	1.0053
σ	10	6.8165	5.8352	6.0054	6.1823
	20	2.9042	2.7856	2.8244	2.8639
	40	1.2031	1.1989	1.2061	1.2133
	60	0.57817	0.5790	0.5807	0.5824
	80	0.17633	0.1765	0.1766	0.1768
ξ	10	5.8591	4.9128	5.0731	5.2396
	20	2.0619	1.9556	1.9880	2.0211
	40	0.56328	0.5599	0.5642	0.5685
	60	0.15504	0.1553	0.1559	0.1565
	80	0.015428	0.0154	0.0155	0.0155
ς	10	2.7297	2.4846	2.5345	2.5861
	20	1.8063	1.7548	1.7745	1.7946
	40	1.0190	1.0163	1.0219	1.0275
	60	0.55005	0.5509	0.5524	0.5540
	80	0.17543	0.1756	0.1757	0.1759

For the purpose of comparison, some numerical examples are cited together in Table 5, which shows that there is but slight difference in the configuration in either way, while a considerable disagreement can be seen in the values of τ, especially in the region of large inclination.

Literature cited

1. Tauti, M.; The force acting on the plane net in motion through the water. Jap. Soc. Scient. Fish., 3(1), 1934, 1.
2. Hidaka, K.; Kaiyô Buturigaku (Physical oceanography. Iwanami Pub. Co.).
3. Thews, J, G. and L. Landweber; On the resistance of a heavy flexible cable for towing a surface float behind a ship. U. S. Exp. Model Basin. Report, No.418, 1936.
4. Landweber, L. and M.H. Protter; The shape and tension of a light, flexible cable in a uniform current. D. W. Taylor Model Basin Report, No. 533, 1944.
5. Pode, L.; An analysis of cable and housing requirements for a deep-towed body at high speed. Ibid., No. 661, 1948.
6. Pode, L.; An experimental investigation of the hydrodynamic forces on stranded cables. Ibid., No. 713, 1950
7. Pode, L.; Tables for computing the equilibrium configuration of a flexible cablei n a uniform stream. Ibid., No. 687, 1951.

The Drag Acting on a Net in a Uniform Current, II

By

Hiroshi FUJITA*

With *2 Tables* and *7 Text-figures*

Introduction

In connection with research on fishing gears, several studies [1][2][3][5] have been published on the flow characteristics of, especially the hydrodynamic forces acting on, a plane net placed in a uniform current. In spite of its more practical interest than in the case of plane net, however, no systematic study appears to have been made of the similar problem concerning nets of curved surface, except for a recent preliminary work of MIYAMOTO[4] on a curtain-like net suspended in a uniform current. As a first approach to this direction, an experimental investigation was carried out using a simple curved surface net as illustrated schematically in Figure 1 as a test model. In the present paper, the data obtained are described along with some theoretical considerations relating to this problem. The theoretical considerations are based chiefly on the experimental informations obtained in Part I[1] of this series of papers on the hydrodynamic behaviour of a plane net.

Experimental Results

The sample net used was the same cotton cord net as that adopted in the author's previous work[1] on a plane net; its mesh was 1 cm., and its netting cord was 1.5 mm. in diameter at wet state. A metal square frame whose side was about 30 cm. was prepared, and the net, after being cut up at desired dimensions from the sample sheet, was fixed up to the frame so as to form a cylindrical surface as is illustrated in Figure 1. In what follows, the net of this shape will be referred to as the *cylindrical net*. For simplicity in mathematical considerations which will be given later, further arrangement was introduced in fixing up the net. It was to realize the case in which two crossing legs in each mesh make right angles everywhere in the net. With this arrangement, netting cords belonging to one family were parallel with each other and to the frame edge AB (see Figure 1), and cords belonging to the other family were paralell to one another and crossed the frame edge AB at right angles. We shall refer to the cord belonging to the former family as the longitudinal cord and to that of the latter family as the transversal cord.

* Laboratory of Applied Physics.

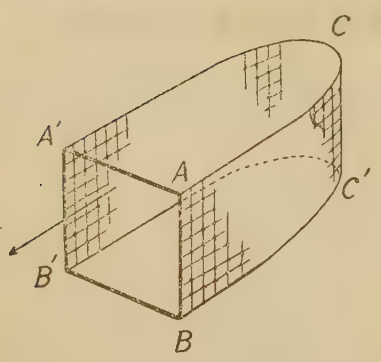


Figure 1.
Schematic view of the test net.

The net was towed in a still water tank in the direction normal to the plane of the frame, and the fluid resistance R to which the net was subjected was measured as a function of towing speed V. The method of experiment was identical with that used in the study of a plane net described in Part I, so that no account is here made of it. Throughout the course of this study, the water temperature in the test tank was not particularly changed from 15°C.

In this study the problem with which particular concern was made was to investigate how the fluid resistance of the net changes with change in depth of the net. Since the actual value of the depth of the net being in advance was comparatively difficult to measure, another parameter of the similar nature was introduced which was the ratio of the arc length, l, of the net to the length, a, of the edge AA'. The value of l/a was varied from 1.0 to 3.5.

Typical examples of the experimental relation of R to V are shown in Figure 2 in the form of $\log R$ plotted against $\log V$. For all cases of l/a tested the experimental plots between $\log R$ and $\log V$ showed a similar appearance as seen from this figure; For lower towing speeds the drag is increased linearly with V in accordance with the Stokes law for fluid resistance, while at higher values of V the Newton's square law for drag is followed. For intermediate values of V, a smooth transition is seen to occur from the Stokes law to the Newton law. These results are essentially the same as those found in Part I with a plane net.

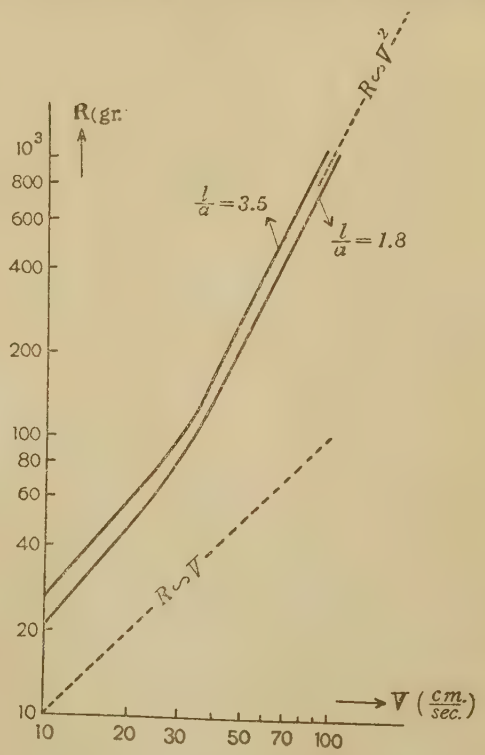


Figure 2. Drag R as a function of towing speed V; l/a is a parameter representing the net depth.

For each value of l/a investigated, values of R/V^2 were computed at $V=60$, 70, and 80 cm./sec. As should be expected from the good establishment of the Newton's square law in this velocity region, the numerical values so calculated accorded well with each other within differences less than about 2 percent. They were averaged arithmetically, and the average r is listed in Table I as a function of l/a. From these data the relative change in r with change in l/a was computed, and is also listed in Table I, where r_0 stands for the value of r at $l/a=1.0$. In Figure 3, this result is shown graphically. It is noted from this figure that even for

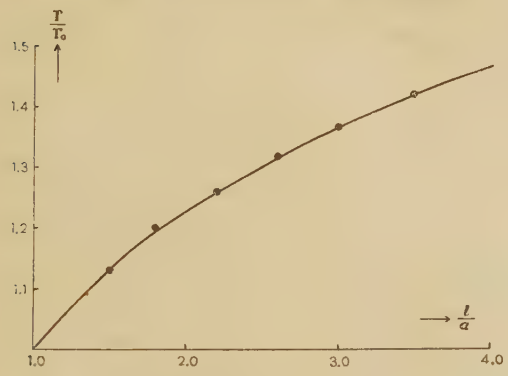


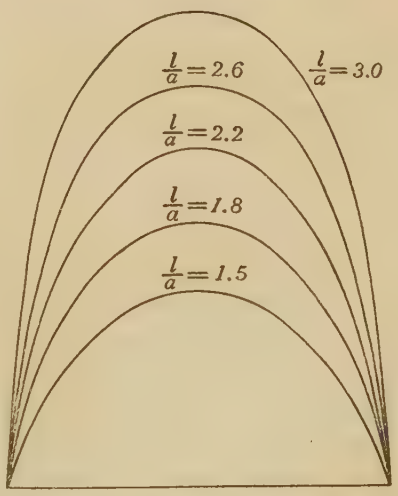
Figure 3. Relative increase in drag with increase in the net depth.

Table 1

l/a	1.0	1.5	1.8	2.2	2.6	3.0	3.5
r	0.75	0.847	0.900	0.944	0.988	1.026	1.069
r/r_0	1.00	1.13	1.20	1.26	1.32	1.37	1.425

values of l/a as large as 3.0 the relative increases in r remain only at low values of about 40 percent. This result may be of some interest in inspecting the fluid resistance acting on a trawler net being towed in the sea.

The net while being towed at constant speed was photographed from above the test tank for a series of values of l/a. A family of curves was thus obtained as shown in Figure 4, which indicates how the shape of the net is changed with increase in the net depth.



Fiureg 4. Vertical view of the net while being towed.

Theoretical Considerations

In this section, the problem above dealt with experimentally is considered from a theoretical point of view in the hope of obtaining a theoretical interpretation of the experimental result plotted in Figure 3.

For this purpose, we shall first assume that the flow past the cylindrical net in question may be regarded as two-dimensional. Further it is assumed that the weight of netting cords in water may be neglected in comparison with the hydrodynamic forces acting on them. With these assumptions, it becomes possible to restrict the subsequent consideration only to the state of affairs at a single transversal cord. Referring to Figure 5, in which the curve ACA' represents any one of the transversal cords and the dots marked on it imply the longitudinal cords crossing it perpendicular to the plane of the sheet, let us consider the element Δs taken along ACA' as indicated. This element is in equilibrium under the action of the system of forces comprising (i) the force P normal to it; (ii) the force F along it; (iii) the tensions T and $T+\Delta T$ at its ends; and (iv) an indirect force K resulting from the fluid force acting on the longitudinal cord corssing it. Flow pattern at each transversal cord is similar, so that it is sufficient for the present calculation if we take into account only the valuve of K with respect to the longitudinal cord of length Δs. According to the experimental information obtained in Part I[1] the forces mentioned above may be expressed by (i) $P=P_0 \sin\theta \cdot \Delta s$, (ii) $F=F_0\cos^2\theta \cdot \Delta s$, and (iv) $K=P_0\Theta(\theta)\cdot\Delta s$, where θ is the angle of incidence of the cord element and $\Theta(\theta)$ is a function representing the hydrodynamic intereference between neighbouring cords placed normal to the stream and a distance Δs apart. In the absence of this interference, $\Theta(\theta)$ takes the value of unity for all values of θ, as to details of which Part I should be referred to. P_0 is the force per unit length of cord when normal to the stream, and F_0 is the force per unit length of the cord when parallel to the stream. Resolving all forces above stated along the cord element, we obtain the equation

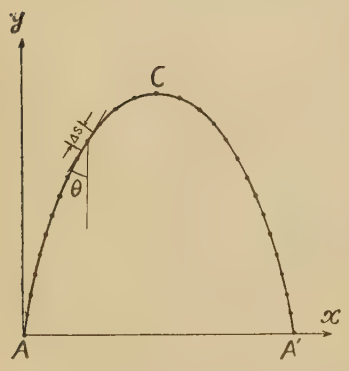


Figure 5. Reference system for the mathematical analysis; ACA' represents a transversal cord, and dots longitudinal cords.

$$\frac{\Delta T}{\Delta s} + P_0\,\Theta(\theta)\,\cos\theta + F_0\cos^2\theta = 0. \qquad (1)$$

Resolving also at right angles to the element, we obtain

$$T\frac{\Delta\theta}{\Delta s} - P_0\sin\theta - P_0\,\Theta(\theta)\sin\theta = 0. \qquad (2)$$

If the mesh is sufficiently small compared with the whole dimensions of the net, the above equations may be transformed to differential forms as

$$\frac{dT}{ds} + P_0 \Theta(\theta) \cos\theta + F_0 \cos^2\theta = 0, \tag{3}$$

$$T\frac{d\theta}{ds} - P_0 \sin\theta - P_0 \Theta(\theta) \sin\theta = 0, \tag{4}$$

where s is the arc length measured from the coordinates origin A (see Figure 5). Let l be the value of s at A', i. e., the arc length of the net defined formerly, and T_0 be T at $s=l/2$, and define the following dimensionless variables:

$$\frac{s}{l} = \sigma, \qquad \frac{T}{P_0 l} = \tau, \qquad \frac{T_0}{P_0 l} = \tau_0, \qquad \frac{F_0}{P_0} = \varepsilon.$$

Then equations (3) and (4) reduce to

$$\frac{d\tau}{d\sigma} + \Theta(\theta) \cos\theta + \varepsilon \cos^2\theta = 0, \tag{5}$$

$$\tau\frac{d\theta}{d\sigma} - [\,1 + \Theta(\theta)\,] \sin\theta = 0, \tag{6}$$

whence we obtain at once

$$\tau = \tau_0 \exp\,[I(\theta)] \tag{7}$$

with $I(\theta)$ defined as

$$I(\theta) = \int_\theta^{\frac{\pi}{2}} \frac{\Theta(\theta)\cos\theta + \varepsilon\cos^2\theta}{[\,1+\Theta(\theta)\,]\sin\theta} d\theta. \tag{8}$$

Introducing equation (7) into equation (5), and integrating, there results

$$\sigma = \tau_0 \int_\alpha^\theta \frac{\exp[I(\theta)]}{[1+\Theta(\theta)]\sin\theta}\, d\theta. \tag{9}$$

where α denotes the angle of incidence at A or at A'. On substituting the geometrically obvious condition that $\sigma = \frac{1}{2}$ at $\theta = \frac{\pi}{2}$ into the above equation, we get

$$\frac{1}{\tau_0} = 2\int_\alpha^{\frac{\pi}{2}} \frac{\exp[I(\theta)]}{[1+\Theta(\theta)]\sin\theta}\, d\theta. \tag{10}$$

At each point on the transversal cord under consideration the abscissa x, the arc length s and the angle of incidence θ are related by the equation

$$\frac{dx}{ds} = \sin\theta.$$

This relation, after being integrated, gives the equation

$$\frac{x}{l} = \tau_0 \int_\alpha^\theta \frac{\exp[I(\theta)]}{1+\Theta(\theta)}\, d\theta,$$

whence it follows at once

$$\frac{a}{l} = 2\tau_0 \int_\alpha^{\frac{\pi}{2}} \frac{\exp[I(\theta)]}{1+\Theta(\theta)}\, d\theta,$$

where a denotes the x-coordinate of point A, so that it is nothing but the quantity defined formerly as the length of the frame edge AA'. The above equation for a/l can be combined with equation (10) to give

$$\frac{l}{a} = \frac{\int_{\alpha}^{\frac{\pi}{2}} \exp\left[I(\theta)\right] / \left[1 + \Theta(\vartheta)\right] \sin\theta \, d\vartheta}{\int_{\alpha}^{\frac{\pi}{2}} \exp\left[I(\vartheta)\right] / \left[1 + \Theta(\theta)\right] d\theta} \tag{11}$$

We shall next calculate the total resistance acting on the net. Denoting this drag by W, it is given by the sum of (i) W_t, the total sum of drags acting on transversal cords involved in the net, and (ii) W_l, the total of drags on longitudinal cords involved, namely,

$$W = W_t + W_l. \tag{12}$$

First, W_t is given by the equation

$$W_t = 2m \int_0^{\frac{l}{2}} (P_0 \sin^2\theta + F_0 \cos^3\theta) \, ds,$$

where m is the number of transversal cords involved in the direction perpendicular to the x-y plane (see Figure 5). The above equation can be transformed to the equation

$$W_t = 2P_0 \tau_0 ml \int_{\alpha}^{\frac{\pi}{2}} \frac{(\sin^2\theta + \varepsilon \cos^3\theta) \exp\left[I(\theta)\right]}{\left[1 + \Theta(\theta)\right] \sin\theta} \, d\vartheta. \tag{13}$$

For W_l it may be shown that

$$W_l = 2P_0 m \int_0^{\frac{l}{2}} \Theta(\vartheta) \, ds,$$

which can also be put into the form

$$W_l = 2P_0 \tau_0 ml \int_{\alpha}^{\frac{\pi}{2}} \frac{\Theta(\theta) \exp\left[I(\theta)\right]}{\left[1 + \Theta(\theta)\right] \sin\theta} \, d\vartheta. \tag{14}$$

Thus, we have for W the expression

$$W = 2P_0 \tau_0 ml \int_{\alpha}^{\frac{\pi}{2}} \frac{\left[\Theta(\theta) + \sin^2\theta + \varepsilon \cos^3\theta\right] \exp\left[I(\theta)\right]}{\left[1 + \Theta(\theta)\right] \sin\theta} \, d\vartheta. \tag{15}$$

It is readily shown that when $l = a$, i. e., when the net is stretched flattly on the frame, the value of W, denotiong it by W_0, is given by

$$W_0 = 2P_0 ma. \tag{16}$$

The ratio of W to W_0 is evidently equal to the ratio r/r_0 defined in the previous section as the relative change in drag. The expression for it can now be obtained from equations (15) and (16) with consideration of equations (10) and (11), giving

$$\frac{r}{r_0} = \frac{1}{2} \cdot \frac{\int_{\alpha}^{\frac{\pi}{2}} \frac{\left[\Theta(\theta) + \sin^2\theta + \varepsilon \cos^3\theta\right] \exp\left[I(\theta)\right]}{\left[1 + \Theta(\theta)\right] \sin\theta} \, d\theta}{\int_{\alpha}^{\frac{\pi}{2}} \frac{\exp\left[I(\theta)\right]}{1 + \Theta(\theta)} \, d\theta}. \tag{17}$$

Equations (11) and (17) are combined to give the relation between r/r_0 and l/a

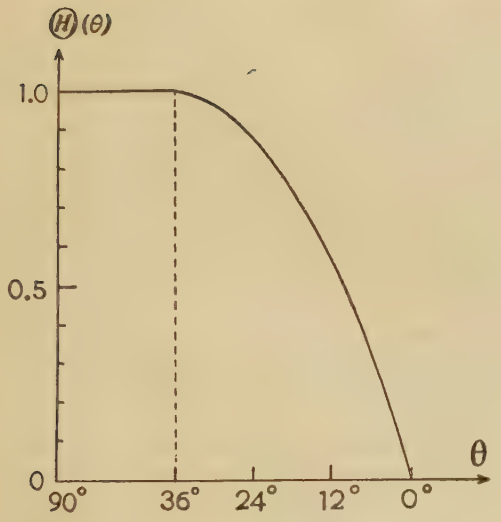


Figure 6. The form of $\Theta(\theta)$, reproduced from Part I.

with α as an intermediate parameter.

Comparison between Theory and Experiment

In evaluating equations (11) and (17) to obtain the explicit form of this relation it is necessary to know the value of ε and the functional form of $\Theta(\theta)$. Since, as has been cited before, the present experiment was carried out using the same net as employed in the previous study for the hydrodynamic behaviour of a plane net, it is reasonable for the present purpose to assign to ε and $\Theta(\theta)$ the results determined experimentally for the plane net. The previous study indicates that the value of ε is to be taken as 0.12 and the form of $\Theta(\theta)$ is to

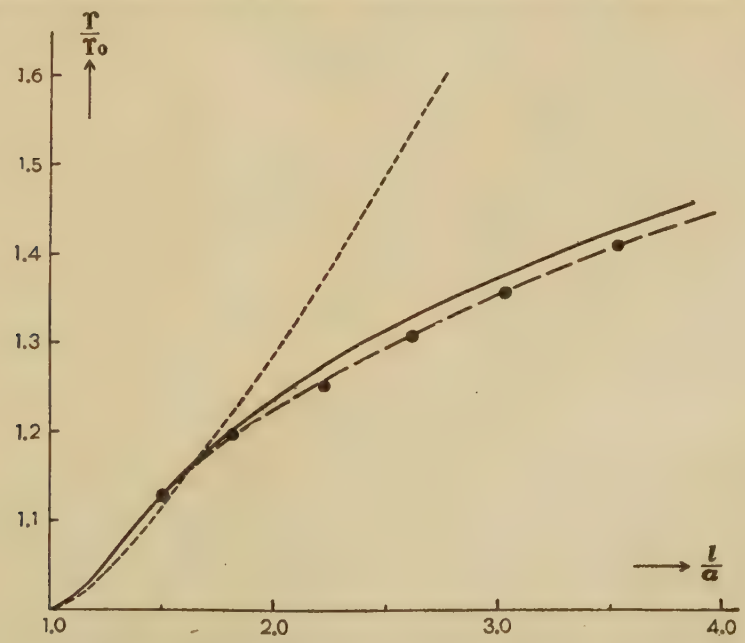


Figure 7. Theoretical results compared with the experimntal one; —— :experimental; ——: theoretical in which the hydrodynamic interference between neighbouring cords is considered; - - - - -: theoretical in which no allowance is made for the hydrodynamic interference.

be assumed as shown graphically in Figure 6. With such assignments to these unknown quantities, numerical calculations of equations (11) and (17) were performed using Simpson's one-third rule, and the plot indicated in Figure 7 with solid line was obtained. The curve thus obtained is seen to be in good accordance with the broken line which was visually drawn to fit the experimental points represented by black circles. Considering the approximations adopted in the theoretical analysis and the experimental difficulties in determining the accurate form of $\Theta(\theta)$ and the value of ε, the agreement of this degree may be regarded as rather striking.

In the above consideration the hydrodynamic interference occurring between neighbouring cords lying perpendicular to the stream was approximately taken into account through the angular variation of $\Theta(\theta)$. In what follows, we shall examine to what conclusion we shall be led if this allowance for the hydrodynamic interference be ignored. This problem can be resolved by carrying out the similar analysis as in the above with the assumption that $\Theta(\theta) = 1.0$ for all values of θ. For simplicity in this analysis, a further condition is introduced that the frictional force may be neglected, i. e., that $\varepsilon = 0$. It was proved that this neglecting of ε did not result in a serious modification of the result to be derived by the subsequent analysis.

Introducing the above mentioned conditions of $\Theta(\theta)$ and ε into equations (11) and (17), and carrying out some deductions, the following equations can be derived:

$$\frac{r}{r_0} = \frac{1}{2} \cdot \frac{\Phi_0(\alpha) + \Phi_2(\alpha)}{\Phi_1(\alpha)}, \tag{18}$$

$$\frac{l}{a} = \frac{\Phi_2(\alpha)}{\Phi_1(\alpha)}, \tag{19}$$

where

$$\Phi_0(\alpha) = \int_{\alpha}^{\frac{\pi}{2}} (\sin\theta)^{\frac{1}{2}} d\vartheta, \tag{20}$$

$$\Phi_1(\alpha) = \int_{\alpha}^{\frac{\pi}{2}} (\sin\theta)^{-\frac{1}{2}} d\theta, \tag{21}$$

$$\Phi_2(\alpha) = \int_{\alpha}^{\frac{\pi}{2}} (\sin\theta)^{-\frac{3}{2}} d\theta. \tag{22}$$

Using the *theta* functions[6] whose parameter q is defined by

$$\left[\frac{\vartheta_2(0)}{\vartheta_3(0)}\right]^2 = \frac{1}{2}, \tag{23}$$

the above three integrals can be evaluated to give

$$\Phi_0(\alpha) = \frac{2\sqrt{2}}{\pi[\vartheta_3(0)]^2}\left\{\frac{\vartheta_4'(u)}{\vartheta_4(u)} - \left[\frac{\pi^2}{2}[\vartheta_3(0)]^4 + \frac{\vartheta''_2(0)}{\vartheta_2(0)}\right]u\right\}, \tag{24}$$

$$\Phi_1(\alpha) = \sqrt{2}\,\pi[\vartheta_3(0)]^2 u, \tag{25}$$

$$\Phi_2(\alpha) = \frac{2\sqrt{2}}{\pi[\vartheta_3(0)]^4}\left\{\left[\frac{\pi^2}{2}[\vartheta_3(0)]^4 + \frac{\vartheta_2''(0)}{\vartheta_2(0)}\right]u - \frac{\vartheta_2'(u)}{\vartheta_2(u)}\right\}, \tag{26}$$

in which the new variable u is associated with α by the equation

$$\pi[\vartheta_3(0)]^2 u = F\left(\frac{1}{\sqrt{2}},\ \cos^{-1}\sqrt{\sin\alpha}\right). \tag{27}$$

Here, $F(k, x)$ is the usual notation of the elliptic integral of the first kind whose modulus and variable are respectively k and x. Substitutions of equations (24), (25), and (26) into equations (18) and (19), after determination of the q value from equation (23), yield

$$\frac{r}{r_0} = \frac{0.228_5}{u}\left\{\frac{1}{\pi}\frac{\vartheta_4'(u)}{\vartheta_4(u)} - \frac{1}{\pi}\frac{\vartheta_2'(u)}{\vartheta_2(u)}\right\}, \tag{28}$$

$$\frac{l}{a} = -0.457\left\{\frac{1}{\pi u}\frac{\vartheta_2'(u)}{\vartheta_2(u)} + 1\right\}, \tag{29}$$

which make it possible to evaluate r/r_0 as a function of l/a. The evaluation may readily be attained by referring, for example, to Jahnke-Emde's table of functions. The resultant plot is shown in Figure 7 by a dotted line. Comparison of three curves plotted in this figure indicates how marked influence is exerted by the hydrodynamic interference between netting cords on the hydrodynamic behaviour of the cylindrical net investigated, especially in cases of larger net depth.

Finally, a concern is made of the change in α with increase in l/a. The thoretical answer for it can be obtained from equation (11), while the experimental one may be found from Figure 4 showing the shape of the net while being towed for a series of values of l/a. These values are listed in Table 2. Allowing for ambiguities in reading the values of α from Figure 4, the agreements indicated must be regarded as good.

Table II

l/a	1.5	1.8	2.2	2.6	2.8
α obs.	20°	13°~14°	8°~9°	6°~7°	3°~4°
α theor.	20.5°	14°	9.5°	7°	5.3°

Summary

As a first approach to find the flow characteristics of curved surface nets placed in a uniform current, a net of cylindrical surface as shown in Figure 1 was taken as the test model for the preset study. By towing this net normal to the plane of the frame at constant speed in a still water tank, the fluid resistance acting on it was measured as functions of towing speed V and of the net depth. The effect of the net depth was represented by a parameter l/a which was defined as the ratio of the arc length, l, of the net to the length, a, of the frame edge AA'. The change in

fluid drag R with V is shown in Figure 2 for different values of l/a. A quantity r was introduced which defined as R/V^2. The relative change in r with change in l/a was computed from experimental data analogous to Figure 2 and plotted in Figure 3 where r_0 is the value of r at $l/a = 1.0$.

A mathematical analysis of the problem dealt with in the experimental part was undertaken based chiefly on the experimental results obtaind in the author's previous study[1] for a plane net. Thus, corresponding to the experimental plot shown in Figure 3 equations (11) and (17) were derived. A reasonably good fit of the theoretical result to the experimental one was found as shown in Figure 7. In developing the above theoretical result an approximate allowance was made for the hydrodynamic inrerference between neighbouring cords lying perpendicular to the general flow past the net. The dotted curve in Figure 7 was derived with neglect of such an allowance for the hydrodynamic interference, indicating the importance of this allowance in interpreting the hydrodynamic behaviour of curved surface nets.

The experimental part of this work was conducted chiefly by Mr. T. YOKOTA to whom the author's thanks are largely due. The author also wishes to express his appreciation to Professor T. KAWAKAMI for invaluable advice given throughout the course of this work. It is to be mentioned that expenses of the present work were partly defrayed by the Ministry of Education.

Literature Cited

1. FUJITA, H., and YOKOTA, T., J. Applied Phys. Japan, **20**, 59–64 (1951).
2. KURITA, S., J. Applied Phys. Japan, **18**, 236–245 (1950).
3. MIYAKE, Y., J. Imper. Fish. Inst., **23** (2), 43–60 (1927).
4. MIYAMOTO, H., Bull. Tokain Regional Fish. Res. Lab., **2**, 1–121 (1951); in particular, pp. 90–97.
5. TAUTI, M., Bull. Japan. Soc. Scient. Fish., **3**, 1–4 (1934).
6. TOMOTIKA, S., "*Theory of Elliptic Functions*" (Kawade Book Co., Tokyo, 1942), p. 120 *et seq.*

Revision of the Japanese Serranid Fish, referable to the Genus *Acropoma*

By

Kiyomatsu MATSUBARA

With 3 Text-figures

In 1938 OKADA and MATSUBARA (P.192) found that the genus *Acropoma* is represented by two forms in Japanese waters and pointed out that the vent opened a short distance behind the ventral fin origin in one form, and farther behind in the other. Subsequently HANEDA examined the luminous organ of these two forms and found that they differ not only in structure of the organ but also in other important features (1939 : 49–52, figs. 1–3 ; 1950 : 215–221, figs. 1–3).

Recently the author examined 56 specimens referable to the genus *Acropoma* in which two distinct forms are recognizable. Upon a careful analysis of these examples and a review of the descriptions given by various authors, the writer came to the conclusion that the two forms represent distinct species. The name *Acropoma japonicum* GÜNTHER is applicable to one form, while the second is a species described herein for the first time as *Acropoma hanedai*. In order to properly delimit the new form the author includes below a redescription of *A. japonicum*.

All counts and measurements included in this report were obtained by the identical methods used by the writer in his previous papers on deep-sea fishes of Japan. The expenses for the investigations of the deep-sea fishes were defrayed by the research fund of the Ministry of Education and Viscount Keizo SHIBUSAWA.

It is a pleasure to record here a debt of gratitude to Dr. Robert R. HARRY at Stanford University for reading the manuscript.

Acropoma japonicum GÜNTHER

Acropoma TEMMINCK et SCHLEGEL, 1847 : 31, pl. 12, figs. 2 and 3, Nagasaki (description).

Acropoma japonicum GÜNTHER, 1859 ; 250 (original description, after TEMMINCK and SCHLEGEL).——JORDAN et SNYDER, 1901 : 912, fig. 10, Wakanoura; Misaki (description). ——? FRANZ, 1910 : 44, Fukuura (short description).——? JORDAN et HUBBS, 1925 : 231, Wakanoura (notes).——WEBER et BEAUFORT, 1929 : 269, fig. 89 (description, after JORDAN and SNYDER).——FOWLER et BEAN, 1930: 145, Tayabar Light and Chocolate Island, Philippines (description).——? SCHMIDT, 1931 : 49, Nagasaki (notes).——YASAKI et HANEDA, 1936 : 55, figs. 1–4, Mimase, Prov. Tosa (notes on luminous organ).——ROXAS et MARTIN, 1937 : 111 (listed)——? Kamohara,

1938: 27, Prov. Tosa (notes).———HANEDA, 1939: 49, figs. 1 and 2. Mimase, Prov. Tosa (notes on luminous organ).———NORMAN, 1939: 58, Gulf of Oman (notes).———SMITH, 1949: 212, pl. 23, fig. 499, off Natal (short description).——— HANEDA, 1950: 215, fig. 1, Mimase, Prov. Tosa (discussion; notes on luminous organ). ———KAMOHARA, 1952: 38, Prov. Tosa (notes).

Acropoma cynodon REGAN, 1921: 415, off Natal (original description).———BARNARD, 1927: 529, Natal coast (description).

Material described.———27 specimens, Nos. 1684–1686, 1688–1701, 1703–1711; and 1720 (the numbers refer to MATSUBARA's fish collection, in which each specimen bears a separate number), 44.8–129.0 mm in standard length (55.9–163.3 mm in total length), off Owasi, Kumano-Nada, January 4–8, 1936; 2 specimens, Nos. 1681 and 1682, 83.0 and 89.7 mm (106.2 and 114.0 mm), off Owasi, January 18, 1936.

DESCRIPTION: D. VIII–1, 10; A. III, 7; P. 15 or 16; scales in lateral line about 50; gill-rakers on first arch 5 or 6 + 16—18 = 21—24.

Head 2.48 to 2.76 in standard length; depth 2.92 to 3.66. Snout 3.33 to 4.46 in head; eye 3.56 to 4.21; upper jaw 2.38 to 2.79; interorbital space 4.37 to 5.67; distance from pelvic fin origin to vent 2.89 to 3.87; same from vent to anal fin origin 1.38 to 1.74; depth of caudal peduncle 3.05 to 3.47; length of the same 1.73 to 2.20; pectoral 1.44 to 1.72; ventral 1.80 to 2.20; longest dorsal spine (third one) 2.09 to 3.25; longest dorsal ray (first or second) 1.92 to 2.44; longest anal spine (third) 3.70 to 5.28; longest anal ray (first) 2.12 to 2.92.

Body compressed and moderately elongate, usually lower than one-third the length of body; the back gently elevated; ventral profile less arched; caudal peduncle much longer than high. Head always longer than one-third the body length.

Mouth rather large. Maxillary greatly expanded posteriorly, the posterior extremity about as wide as the diameter of the pupil, the hind edge either truncated or shallowly concave, extending posteriorly as far as a vertical through anterior one-third of the eye or a little beyond, sometimes to below the middle of the eye; the anterior two-thirds of the bone largely hidden under the preorbital bones. Lower jaw projecting beyond the upper when mouth is closed; symphyseal knob evident, but small.

Teeth cardiform on lower jaw, but villiform elsewhere. The cardiform teeth set in a single series, widely separated from each other. The villiform teeth uniform in size on upper jaw, but enlarged posteriorly on vomer and anteriorly on palatines. The villiform band is much broader on upper jaw than on vomer and palatines. More or less enlarged teeth, about 10 in number, running in a sub-terminal series outside the villiform band on upper jaw. A pair of large canines in front of the upper jaw and 1 or 2 pairs of similar ones at the symphyseal part of the lower jaw. Tongue toothless and rounded at the tip.

Snout moderately long, about as long as, shorter, or a little longer than diameter

of eye. Eye large, never projecting above the general upper profile of head. Nostrils, two on each side, ellipsoid in shape and moderately large, the anterior one fringed by a low dermal flap posteriorly. Interorbital space more or less elevated, narrower than diameter of eye or than length of snout, and a low ridge running in the middle. Preopercle double edged, the posterior part papery and the hind edge smooth or with several very weak spinules. Antero-lower edge of subopercle and postero-lower edge of interopercle finely serrated, but the serrations hardly visible to an unaided eye. Subopercle greatly produced posteriorly into a thin flap, the tip armed with 2 to 4 weak denticulations. Gill-opening very wide, beginning at the insertion of the lateral line, extending forwards as far as slightly beyond a vertical through the anterior nostril.

Gill-rakers long, slender and compressed, the tips bluntly pointed, the longest one on first arch 1.20 to 2.64 in diameter of eye and much longer than the longest gill-lamella. Pseudobranchiae well developed, the longest lamella about as long as the diameter of pupil.

Vent always much nearer the origin of the ventral fin than the insertion of the anal fin.

Scales thin, deciduous and weakly ctenoid. Head naked except for the cheek and opercle; basal parts of pectoral, second dorsal, anal and caudal scaly; other parts of the fins naked.

Membranes of the fins very thin. Dorsal spines weak, the third spine the longest, but usually shorter than the longest soft dorsal ray and not reaching the second dorsal when the fin is laid back; base of the first dorsal much longer than that of the second dorsal. Anal inserted under the middle of base of second dorsal; anal spines weak and the first two spines very small, the third spine the longest, but weak and much shorter than the longest soft anal ray. Outer edges of both second dorsal and anal fins shallowly concave. Pectoral long and pointed, but never reaching the insertion of the anal fin. Ventral much shorter than pectoral, the tip extending far beyond the vent; ventral spine long and slender, but very weak. Caudal deeply forked.

In life the body light pink, the lower half abruptly silvery; fins also pinkish. In formalin, however, the upper half of the body light greyish brown, paler below, the two colors are rather sharply defined; a more or less indefinite dusky band running longitudinally on lower half of the body and many dark brown pigments crowded below the band; opercle blackish brown; vent pale, but surrounded by many dark brown pigments; fins pale, but the dusky pigments running along the basal half of the rays of ventral and anal.

The above description is founded upon the aforementioned 29 specimens.

REMARKS: It should be mentioned that the counts of both dorsal and anal rays are constant in my material. But there are rather noticeable individual

variations in proportions of the body parts except head, maxillary, distance between vent and origin of anal fin, depth of caudal peduncle, length of same, pectoral and ventral.

According to YASAKI and HANEDA (1936 : 55, figs. 1–4) and HANEDA (1939 : 49, figs. 1–2 ; 1950 : 215, fig. 1) a pair of cylindrical luminous organs, in which symbiotic luminous bacteria were found, run longitudinally in the abdominal muscle along each side of the ventral median line from breast to slightly beyond the vent, and are joined with each other at their anterior extremities. The organ, therefore, is U-shaped, about as long as the length of snout plus eye diameter.

These specimens agree well with the description and illustration of TEMMINCK and SCHLEGELS' *Acropoma*, upon which *japonicum* was erected by GÜNTHER, in position of the vent and other features.

Attention should be called to *Acropoma aponicum* described by JORDAN and SNYDER (1901 : 912, fig. 10) which differs from my specimens in having a larger eye, and a slightly fewer number of both dorsal spines and gill-rakers on first gill-arch. Even if such discrepancies really exist, their identification may be correct since the agreement of the position of the vent and other important features are beyond doubt.

As already suggested by WEBER and De BEAUFORT (1929 : 368) the *Acropoma japonicum* of FRANZ (1910 :44) is probably referable to *Synagrops* GÜNTHER inasmuch as he described it as "Bei Exemplaren bis zu 11 cm Länge liegt der After noch unmittelbar vor der Analen." In my 29 specimens ranging from 55.9 to 163.3 mm in total length the vent is without exception much nearer the origin of the ventral than the origin of the anal.

The descriptions of *Acropoma japonicum* given by JORDAN and HUBBS (1925 : 231), SCHMIDT (1931 : 49), and KAMOHARA (1938 : 27 ; 1952 : 38) are all too brief to be indentifiable.

Acropoma japonicum reported by FOWLER (1927 : 259), FOWLER and BEAN (1930 : 145), SMITH (1949 : 212, pl. 23, fig. 499), and *Acropoma cynodon* by REGAN (1921 : 415), and BARNARD (1927 : 529) are all referable to the present species although discrepant from the original description and figures of this species in some meristic characters and body proportions.

FOWLER and BEAN (1930 : 145) regarded *Synagrops splendens* LLOYD (1909 : 159, pl. 47, fig. 5), which should go as *Acropoma splendens* (LLOYD), as a synonym of the present species without giving any sound basis. But LLOYD'S species may be distinct from the present one inasmuch as he gives in his description of his species as "the vent lies between the ventral fins at the level of the opercular angle."

As already pointed out by earlier authors (ALCOCK, 1896 : 311 ; REGAN, 1905 : 329 ; FOWLER, 1930 : 138) the *Acropoma philippiense* GÜNTHER (GÜNTHER, 1880 : 51) is referable to the genus *Synagrops* and quite different from the present species.

Acropoma hanedai, new species

Haneda-hotarujako (new Japanese name)

Holotype.——No. 1712 (MATSUBARA's Fish Collection), 117.0 mm in standard length (145.0 mm in total length), Kumano-Nada, January 4–8, 1936.

Paratypes.——23 specimens, Nos. 1713–1735, 72.5–112.5 mm (93.0 – 142.0 mm), date the same as holotype; 1 specimen, No. 1683, 86.3 mm (108.1 mm), Kumano-Nada, January 10, 1936; 2 specimens, Nos. 4206 and 4210, 80.0 and 87.5 mm (97.0 and 106.2 mm), Kumano-Nada, January, 1937.

DESCRIPTION: D. Ⅷ–I, 10; A. Ⅲ, 7; P. 16; scales in lateral line about 46; gill-rakers on first arch 5 + 16 = 21.

Head 2.66 in body length; depth 3.36. Snout 3.70 in head; eye 3.67; maxillary 2.66; interorbital space 4.31; distance from origin of ventral to vent 1.96; same from vent to origin of anal fin 2.67; depth of caudal peduncle 3.17; length of the same 2.37; pectoral 1.52; ventral 2.16; longest dorsal spine (third one) 2.46; longest soft dorsal ray (first) 2.08; longest anal spine (third) 3.83; longest soft anal ray (first) 2.62.

Body compressed, moderately elongate, the greatest depth less than length of head or than one-third the length of body; the back gently and more or less evenly elevated; ventral outline less arched; caudal peduncle robust, but much longer than deep. Head conical in lateral profile, a little longer than one-third the length of body.

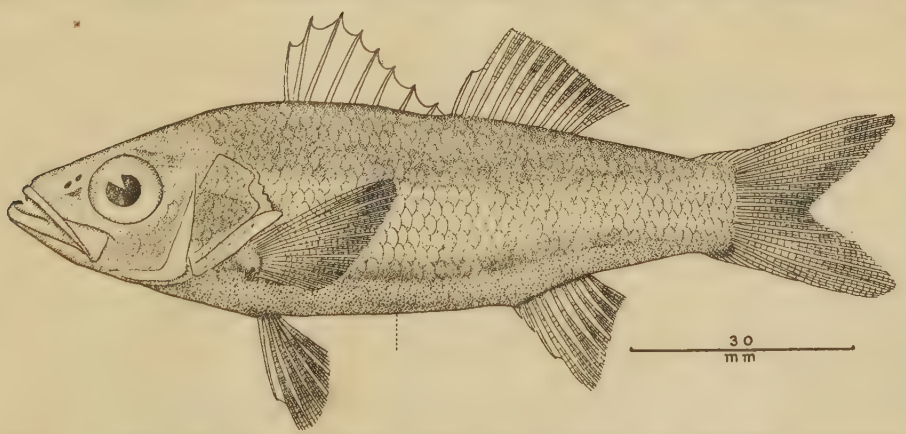


Fig. 1. *Acropoma hanedai*, new species. Female paratype (No. 1716), 96.1 mm in standard length (118.7 mm in total length). Drawing by Kiyomatsu MATSUBARA.

Mouth rather large. Maxillary extending slightly beyond a vertical through the anterior edge of pupil; the bone greatly expanded posteriorly, the posterior extremity about as wide as the diameter of pupil, the hind edge truncated; the anterior two-thirds of the bone largely hidden under the preorbital bones. Lower jaw projecting beyond the upper when mouth is closed; symphyseal knob small; anterior half of the lower jaw decurved, and therefore, the distal part of the jaw more or less hooked upward.

Teeth on lower jaw cardiform, but those on the posterior part canine-like; the teeh set in a single series and widely separated from each other. Teeth villiform on upper jaw, vomer and palatines, but the outer ones on upper jaw, the posterior ones on vomer and anterior ones on palatines enlarged. The villiform band much broader on upper jaw than on vomer or palatines. A pair of enlarged canines in front of each upper and lower jaw, but the former ones much larger than those of the latter. Tongue edentulous and rounded at the tip.

Snout about as long as eye diameter. Eye much longer than interorbital width and never projecting above the upper profile of head. Nostrils, two on each side, elliptical in shape and subequal in size, but the anterior one carrying a low dermal valve posteriorly. Interorbital space slightly elevated, narrower than length of snout or than diameter of eye. Preopercle double-edged, the posterior part very thin. Angular edge of the preopercle, antero-lower edge of subopercle and postero-lower edge of interopercle finely denticulated, but the serrations hardly visible to the naked eye. Subopercle produced posteriorly into a thin flap, but the tip edentulous. Gill-opening very wide, inserted at the origin of the lateral line and extending forward slightly beyond a vertical through the anterior nostril.

Gill-rakers long, slender and compressed, the tips bluntly pointed and their inner edges finely denticulated; the longest one on first arch 2.07 times in diameter of eye. Pseudobranchiae well developed, the longest lamella about as long as the diameter of pupil.

Vent nearer the insertion of the anal fin than that of the ventral fin, just opposite being the case with the former species.

Scales thin, deciduous, and cycloid (at least those on the underside of caudal peduncle); cheek and opercle scaly, but other parts of the head naked. Fins lacking the scales except the basal parts of second dorsal, anal, pectoral and caudal where the small scales are crowded.

Membranes of all the fins very thin. Dorsal spines slender and weak, the third spine the longest, but never reaching the insertion of second dorsal when the fin is depressed; base of the first dorsal about 1.2 times as long as that of the second dorsal; the longest soft dorsal ray (first one) 1.18 times that of the longest dorsal spine. Anal begins a vertical through the middle of base of second dorsal; anal spines weak, the first one minute, the second one about as long as half the length of the third spine; soft anal rays slender, the longest one about 1.5 times as long as the third anal spine. Outer edges of both second dorsal and anal fin shallowly concave. Ventral scarcely reaching the vent; ventral spine long and weak, but much shorter than the longest ventral soft ray. Pectoral long and pointed, about 1.4 times as long as the ventral fin, but never reaching the origin of anal fin. Caudal deeply forked.

In life the body purplish red, the lower half abruptly silvery; fins also reddish.

In formalin, however, upper half of the body greyish brown, much paler below, these two colors rather sharply defined ; a dusky band running longitudinally on lower half of the body and many dark brown spots crowded below the band ; ventral side of body dusky ; cheek and opercle also blackish brown ; vent jet black. Basal parts of pectoral, ventral and anal, and lower part of the base of the caudal blackish ; other parts of the fins pale, but the dusky spots running along the rays of ventral and anal fins.

The above description is based upon the holotype.

The counts and measurements observed in 26 paratypes run as follows : D. VIII-I, 10; A. III, 7; gill-rakers on first arch 4 to 6 + 14 to 16 = 18 to 22. Head 2.50 to 2.78 in body length ; depth 3.15 to 3.66. Snout 3.33 to 4.56 in head ; eye 3.20 to 3.98 ; maxillary 2.45 to 2.82 ; interorbital space 3.97 to 5.00 ; distance from origin of ventral to vent 1.77 to 2.43 ; same from vent to origin of anal fin 2.05 to 2.97 ; depth of caudal peduncle 2.78 to 3.31 ; length of the same 1.88 to 2.38 ; pectoral 1.39 to 1.86 ; ventral 1.84 to 2.36 ; longest dorsal spine 2.48 to 3.93 ; longest soft dorsal ray 2.12 to 2.72 ; longest anal spine 3.47 to 4.52 ; longest soft anal ray 2.22 to 3.18. Longest gill-raker on first arch 1.63 to 2.58 in diameter of eye.

REMARKS : In this species there exist rather extensive individual variations in body proportions except head and maxillary, while the counts of both dorsal and anal rays are constant in my 27 specimens.

In my specimens the angular edge of the preopercle, antero-lower edge of subopercle and postero-lower edge of interopercle are all finely serrated, although scarcely visible to an unaided eye. Scales are entirely torn away except those on the underside of caudal peduncle. These scales are, so far as my investigations go, all cycloid. In my 22 specimens the eye, on its lower half excluding pupil, is strongly reflected with silver which, in some specimens, surrounds the entire pupil. Vent always jet black.

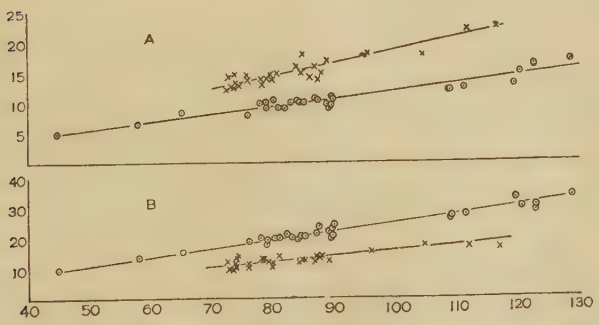


Fig. 2. Comparison of *Acropoma japonicum* and *A. hanedai* in the position of the vent. The distance (in mm) from origin of ventral to vent and same from vent to origin of anal fin (vertical scale) graphed against standard length in mm (horizontal scale). A, distance from origin of ventral to vent ; B, same between vent and origin of anal fin. ⊙, *A. japonicum*; ×, *A. hanedai*. Two species are sharply defined in these two characters. Drawing by Tamotsu IWAI.

The luminous organ of this fish, according to HANEDA (1939: 49–52, figs. 1–3; 1950: 215-221, figs. 1-3) fundamentally agrees with that of the former one in structure, but much longer (about 3 times as long as the length of the snout plus eye diameter in illustration), extending from isthmus to slightly beyond the origin of the anal fin and joined with the opposite fellow immediat-

ely in front of the anal fin instead of being much shorter and connected at the anterior extremity in *Acropoma japonicum*. He also pointed out the following important differences of this fish from the preceding one: 1) body is a purplish red dorsally, but pale red in the preceding one; 2) scales are extremely deciduous instead of being firmly fixed; 3) vent opens further behind than in the precedent; 4) vent is strongly black pigmented, but white in the other one; 5) canine teeth are absent, but well developed in the other one; 6) the fish is found in deeper water than in the other one; 7) full grown ova are found in December to February in the present fish, while in October in the other one. He found, moreover, in these two fish quite a different kind of symbiotic luminous bacteria from the organ. According to my examination, however, a pair of enlarged canines are found in front of each upper and lower jaw in this species as is the case with the former one.

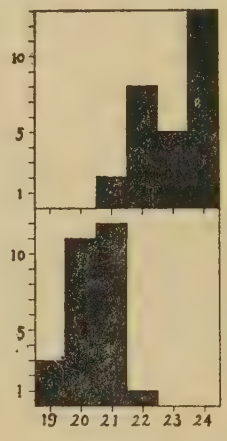


Fig. 3. Comparison of *Acropoma japonicum* and *A. hanedai* in number of gill-rakers on first arch. The histogram for each species shows the frequency distribution of the gill-raker. Upper, *Acropoma japonicum*; lower, *A. hanedai*. Drawing by Kiyomatsu MATSUBARA.

To indicate the differences of this fish from *A. japonicum* more satisfactorily the writer plotted the distance (in mm) from the origin of ventral to vent and same from vent to origin of anal fin (vertical scale) against standard length in mm (horizontal scale), and indicated the frequency distribution of the gill-rakers on first arch by histogram for each species (Figs. 2 and 3). From these studies the writer has found that the present species definitely differs from *A. japonicum* in the position of the vent and in number of gill-rakers on first arch.

Apart from these proportional and meristic characters the writer has found that the present species is distinguished from the other in having the serrations along the angular edge of preopercle (entirely or nearly smooth in *A. japonicum*), strong silvery reflection on lower half of the eye, darker belly and breast, and jet black vent.

Literature

ALCOCK, A. W. (1896), A supplementary list of the marine fishes of India, with descriptions of 2 new genera and 8 new species. Asiatic Soc. Bengal, Journ. 65: 301–338.

BARNARD, K. H. (1927), A monograph of the marine fishes of South Africa. Part II. South African Mus., Ann. 21 (2): 419–1065, figs. 19–32, pls. 18–37.

FOWLER, H. W. and B. A. BEAN (1930), The fishes of the family Amiidae, Chandidae, Duleidae, and Serranidae, obtained by the United States Bureau of Fisheries steamer "Albatross" in 1907 to 1910, chiefly in the Philippine Islands and adjacent seas. U. S. Nat. Mus., Bull 100, 10: i–viii, 1–334, figs. 1–27.

FRANZ, V. (1910), Die japanische Knochenfische der Sammlungen HABERER und DOFLEIN. In Beiträge zur Naturgeschichte Ostasiens. Bayer Akad. der Wiss., Abhandl. Suppl. IV, I: 1–135, figs. 1–7, pls. 1–11.

GÜNTHER, A. (1859), Catalogue of the fishes in the British Museum 2: xxxi + 542 pp.

———(1880), Report on the shore fishes procured during the voyage of H. M. S. "Challenger" in the years 1873–76. Report on the Scientific Results on the Voyage of H. M. S. "Challenger." Zoology 1 (6): 1–82, pls. 1–32.

HANEDA, Y. (1939), New type of luminous organ of the fishes (in Japanese). Reikô [Cold Light] 1: 48–55, figs. 1–7.

———(1950), Luminous organs of fish which emit light indirectly. Pacific Science 4(3): 214–227, figs. 1–6.

JORDAN, D. S. and C. L. HUBBS (1925), Record of fishes obtained by David Starr JORDAN in Japan, 1922. Carnegie Mus., Mem. 10 (2): 93–346, fig. 1, pls. 1–8.

———and J. O. SNYDER (1901), A review of the cardinal fishes of Japan. U. S. Nat. Mus., Proc. 23 (1240): 891–913, figs. 1–10; pls. 43–44.

KAMOHARA, T. (1938), On the offshore bottom-fishes of Prov. Tosa, Shikoku, Japan. 86 pp., 43 figs. Maruzen Co. Ltd.

———(1952), Revised descriptions of the offshore bottom-fishes of Prov. Tosa, Shikoku, Japan. Kôchi Univ. Nat. Sci., Rep. (3): 1–122, figs. 1–100.

LLOYD, R. E. (1909), A description of the deep-sea fish by the R. I. M. S. ship "Investigator" since the years 1900, with supposed evidence of mutation in *Malthopsis*. Ind. Mus., Mem. 2 (3): 139–180, figs. 1–8, pls. 44–50.

NORMAN, J. R. (1939), Fishes. The John MURRAY Expedition 1933–34. Scientific Reports 7 (1): 1–116, figs. 1–41.

OKADA, Y. and K. MATSUBARA (1938), Keys to the fishes and fish-like animals of Japan (in Japanese). XL + 584 pp., 113 pls. The Maruzen Co., Ltd.

REGAN, C. T. (1905), On fishes from the Persian Gulf, the sea of Oman and Karachi, collected by Mr. F. W. TOWNSEND. Bombay Nat. Hist. Soc., Journ. 16 (2): 318–333.

———(1921), New fishes from deep water off the coast of Natal. Ann. Mag. Nat. Hist. (9) 7: 412–420.

ROXAS, H. A. and C. MARTIN (1937), A check list of Philippine fishes. Commonwealth of the Philippine Department of Agriculture and Commerce, Technical Bull. 6: 314 pp.

SCHMIDT, P. J. (1931), Fishes of Japan collected in 1901, Pac. Comm. Acad. Sci. USSR, Trans. 2: i–ii, 1–185.

SMITH, J. L. B. (1949), The sea fishes of southern Africa. xvi + 550 pp., 105 pls. Central News Agency Ltd., South Africa.

TEMMINCK, C. T. and H. SCHLEGEL (1842–50), Pisces. SIEBOLD's Fauna Japonica. 323 pp., 144 pls. Leiden.

WEBER. M. and L. F. De BEAUFORT (1929), Fishes of Indo-Australian Archipelago 5: 458 pp.

YASAKI, Y. and Y. HANEDA (1936), Über einen neuen Typus von Leuchtorgan in Fische. Imp. Acad., Proc. 12 (2): 55–57, figs. 1–4.

Studies on the Biochemical Activities of Marine Bacteria II

On the Properties of Agar-digesting Enzyme of *Vibrio purpureus*

By

Hajime KADOTA*

With 2 Tables 5 Figures and 2 Plates

In the first paper in this series [1] the present author reported that *Vibrio purpureus* rapidly reduced the viscosity of agar and yielded a large quantity of reducing sugar when it was grown in a synthetic medium containing agar as a source of carbon.

The present paper describes the properties of the agar-digesting enzyme obtained from the culture of *Vibrio purpureus* as well as the identification of the reducing sugar resulting from its action on agar.

The enzymatic digestion of agar has been reported by several investigators.[2-12] Most of the previous works, however, have merely been concerned with the existence of such enzyme in some kinds of organisms, and, therefore, our knowledges of this enzyme are far from being satisfactorily understood.

Suchbeing the case, the present author attempted this study from various standpoints in order to clearly make out the general properties of this enzyme.

Effects of various factors on the enzyme activity

The effects of temperature, pH value and NaCl concentration on the activity of the agar-digesting enzyme were investigated with the culture filtrates of *Vibrio purpureus* on the basis of viscosity measurements and reducing sugar analysis.

Preparation of the enzyme solutions: The culture medium employed was the synthetic medium 1,[1] but contained 0.3 % agar as a carbon source. Erlenmeyer flasks of the capacity of 1000 cc. containing 500 cc. of this medium were inoculated and incubated with agitation at 25°C. After 7 days the cultures were filtered through a bacterial filter. Where necessary the filtrates were preserved with toluene (0.1 %).

Reducing sugar analysis and viscosity measurements: Reducing sugars produced in the enzymatic hydrolysates were determined as galactose by Bertrand method. The viscosity was determined by a Ostwald viscosimeter at 50°C and the results were expressed as relative viscosity.

* Microbiological Laboratory

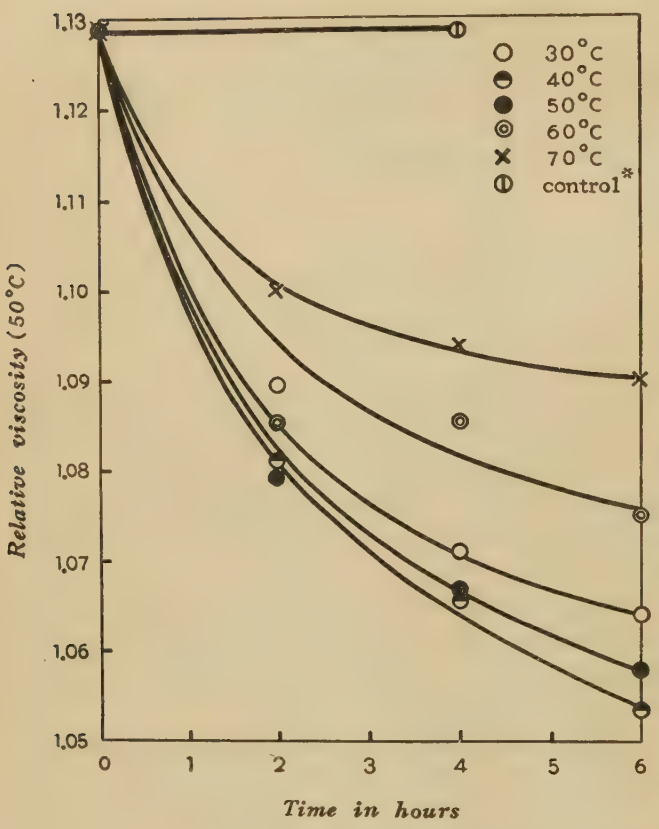


Fig. 1. Effect of temperature on the rate of enzymatic digestion of agar.

Results from viscosimertic assay.

* Experiment with the filtrate inactivated by heating. (at 100°c for 20 minutes)

1. Effect of temperarure

The effect of temperature on the activtiy of the enzyme was determined by following the viscosity change at five temperatures; 30°, 40°, 50°, 60° and 70°C.

Two hundred cc. of the enzyme–substrate mixture (100 cc. of the culture filtrate plus 100 cc. of 0.2% agar solution; pH 6) was placed in Erlenmeyer flasks of the capacity of 300 cc. and incubated under toluene at the desired temperature.

Samples were removed from the incubating enzyme-substrate mixtures at inter–vals of 2 hours and the changes in relative viscosity of them were measured. (Fig. 1) (Fig. 2)

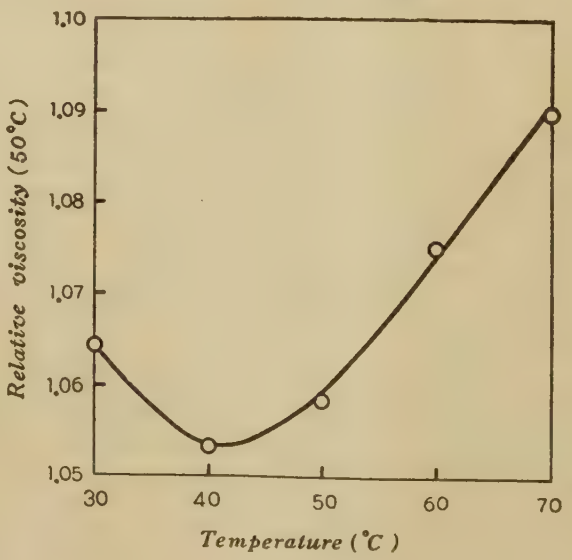


Fig. 2. Effect of temperature on the activity of agar–digesting enzyme.

Viscosimetric data after 6 hours' incubation.

The results indicate that the optimum temperature for this enzyme occurs between 40°–50°C. This enzyme is less active at 60°C than at 30°C. Above 70°C the enzyme is remarkably inactivated. When the enzyme had previously been inactivated by heating, the viscosity change was negligible after 4 hours' exposure at 50°C. (Fig. 1 ; control)

2. Effect of hydrogen ion concentration

The effect of hydrogen ion concentration on the activity of the enzyme was investigated by measuring the viscosity changes and by determining reducing sugars formed in the enzyme-substrate mixtures.

The mixtures contained 100 cc. of 0.2 % agar, 50 cc of McIlvaine's standard buffer solution of the desired hydrogen ion concentrations (in the range of pH 3.2–7.8), 50 cc. of the culture filtrate and a small amount of toluene. These mixtures were incubated for 6 hours at 40°C., and the increase of reducing sugars and the change in relative viscosity were measured by the foregoing methods. (Fig. 3)

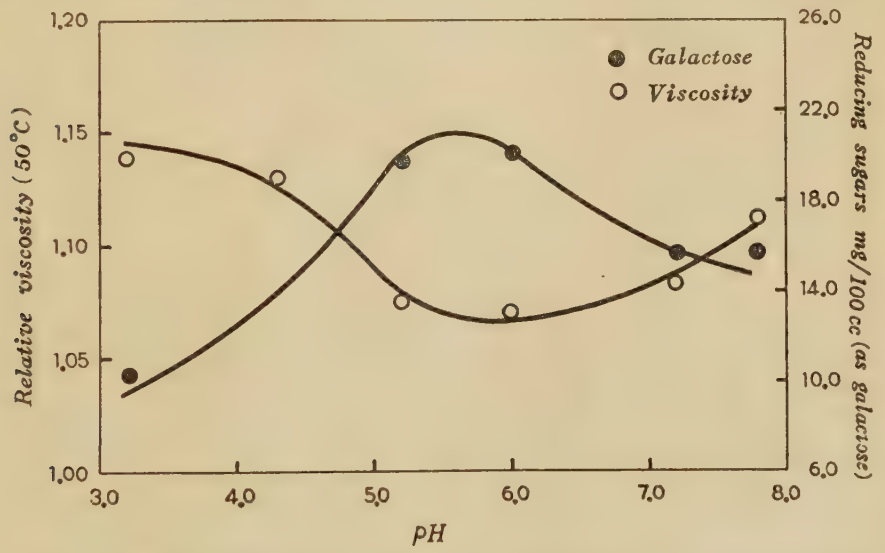


Fig. 3. Effect of hydrogen ion concentration on the activity of the agar-digesting enzyme (after 6 days' incubation at 40°C).

For this enzyme, the data obtained from reducing sugar analysis indicate that the pH optimum is 5.2 to 6.0.

This enzyme is almost inactive at pH 3.2, while it still remains comparatively active at pH 7.8. And also the data obtained from the viscosity test similarly indicate the above mentioned fact.

The pH change during the course of the hydrolysis is negligible, as is also the change in the initial viscosity due to different hydrogen ion concentrations, except pH 3.2.

At pH 3.2, the initial viscosity is slightly lowered.

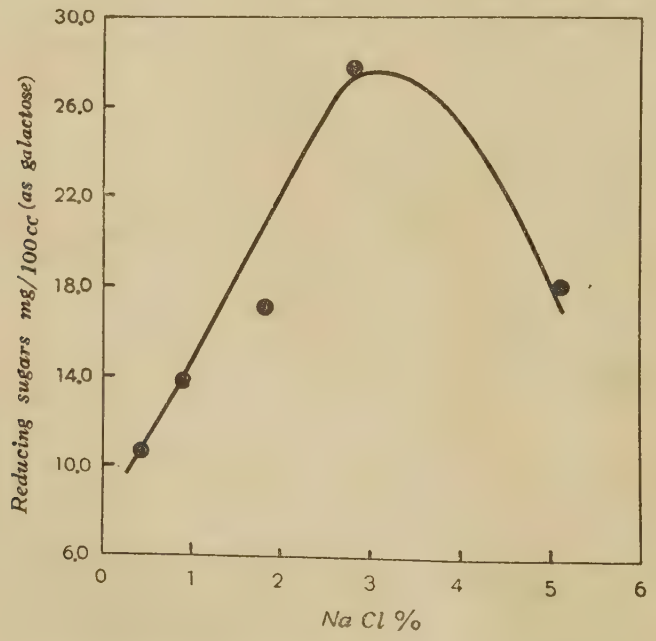
The change in initial amounts of reducing sugars was negligible, due to different hydrogen ion concentrations.

3. Effect of sodium chloride

For the removal of salts, the culture filtrates were dialyzed for 120 hours against running water and then for 48 hours against large volumes of distilled water with a small amount of toluene added as a preservative.

The effect of NaCl on the activity of the enzyme was determined as follows: To a series of six NaCl solutions (100 cc. each) covering the concentrations range from 0 to 10 %, 50 cc. of 0.2 % agar solution, and 50 cc. of dialyzed culture filtrate were added and incubated at 40°C. The pH value of this mixture was 5.8.

A small amount of toluene was added to the mixtures as a preservative. After 6 hours reducing sugars produced in the reaction mixtures were determined. (Fig. 4)



Fg. 4. Effect of NaCl on the activity of agar-digesting enzyme (after 6 hours' incubation at 40°C.)

Fig. 4 illustrates that this enzyme shows the highest activity when the enzyme-substrate mixture contains NaCl in 2.8–3.75 %. The optimum concentration of NaCl for the enzymatic hydrolysis thus appears to be related to the organism from which the filtrate is derived.

Course of agar-digestion by the culture filtrate

The course of formation of reducing sugars and that of decrease in relative viscosity during the enzymatic digestion of agar were observed under the optimum condition of this enzyme.

The enzyme-substrate mixture which contained 200 cc. of the culture filtrate, 400 cc. of 0.3 % agar solution and 200 cc. of McIlvaine's standard buffer solution (pH 6.0) was placed in Erlenmeyer flask of the capacity of 1000 cc. and incubated under toluene at 40°C.

After standing for a definite time, samples were removed from the reaction mixtures and the increase of reducing sugar and the change in relative viscosity were measured. The results are presented in Fig. 5 and show that the amount of reducing sugars reached the maximum value (31.5 mg/100 cc.), after 22 to 24 hours' incubation.

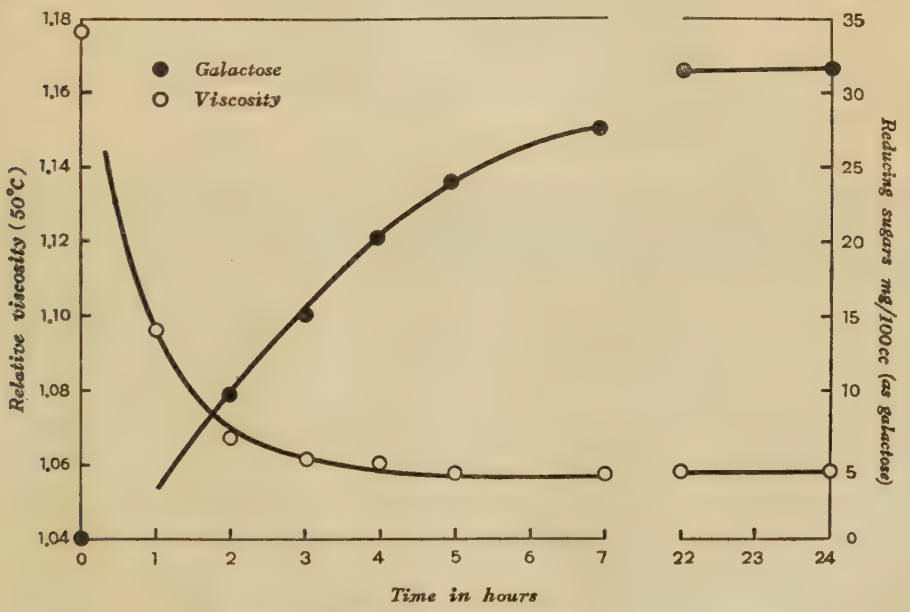


Fig. 5. Course of the formation of reducing sugars and of the decrease of relative viscosity during the enzymatic digestion of agar.

As shown in Fig. 5, the rate of the formation of reducing sugars, during the digestion of agar, follows a curve, which seems to fit the equation:

$$k = \frac{1}{t} \ln \frac{a}{a-x}$$

where
- x = reducing sugars produced
- a = asymptotic value approached by x
- t = time
- k = velocity constant

The velocity constant of the reaction calculated from the data presented in Fig. 5, using the foregoing equation, is shown in Table 1.

Table 1. Velocity-constant of the reaction $a^*=163$

t	x	$k=\frac{1}{t}\ln\frac{a}{a-x}$
2	9.7	0.0134
3	15.1	0.0141
4	20.4	0.0145
5	23.5	0.0135
7	26.6	0.0111

From the data illustrated in Table 1, it is obvious that the process of the formation of reducing sugars obeys the monomolecular reaction within a certain range.

Identification of reaction products in the enzymatic hydrolysate of agar

In the present experiment mucic acid test and paper chromatographic analysis were applied to the identification of the end products formed from agar by the action of the agar-digesting enzyme.

Preparation of the enzymatic hydrolysate of agar: Erlenmeyer flask of the capacity of 1000 cc. containing 500 cc. of the synthetic medium 1 [1] was inoculated and incubated at 25°C.

After 7 days' incubation liquefied agar in the culture was filtered. The filtrate was heated at 100°C for 30 minutes and filtered again through a bacterial filter.

The cell free filtrate was passed through freshly regenerated Diaion K** cation exchange and Diaion A** anion exchange resins to remove salts originally presented in the culture medium.

After the removal of salts the filtrate was evaporated and concentrated at 100°C to 1/10 the original volume.

This solution was subjected to mucic acid test and paper chromatography.

1. Confirmation of the presence of galactose in the enzymatic hydrolysate by mucic acid test

Galactose produced in the hydrolysate was confirmed as follows: 10 cc. of the concentrated hydrolysate was added with 10 cc. of HNO_3 (s.g. 1.15) and evaporated at 87°C to a final volume of 2–3 cc. After the concentrate had been cooled, 5 cc. of distilled water was added to it. Three days later, fine crystals appeared in the solution. (Plate 1)

---

* Amount of reducing sugars (mg/100 cc.) produced in the hydrolysate of the enzyme-substrate mixture perfectly hydrolyzed by sulfuric acid. (20 cc. of the enzyme-substrate mixture was hydrolyzed with 20 cc. of 0.25% H_2SO_4 at 100°C for 90 minutes)

** available from the Mitsubishi Kasei Co.

Plate 1. Crystals developed in the concentrated hydrolysate which was oxidized by HNO_3

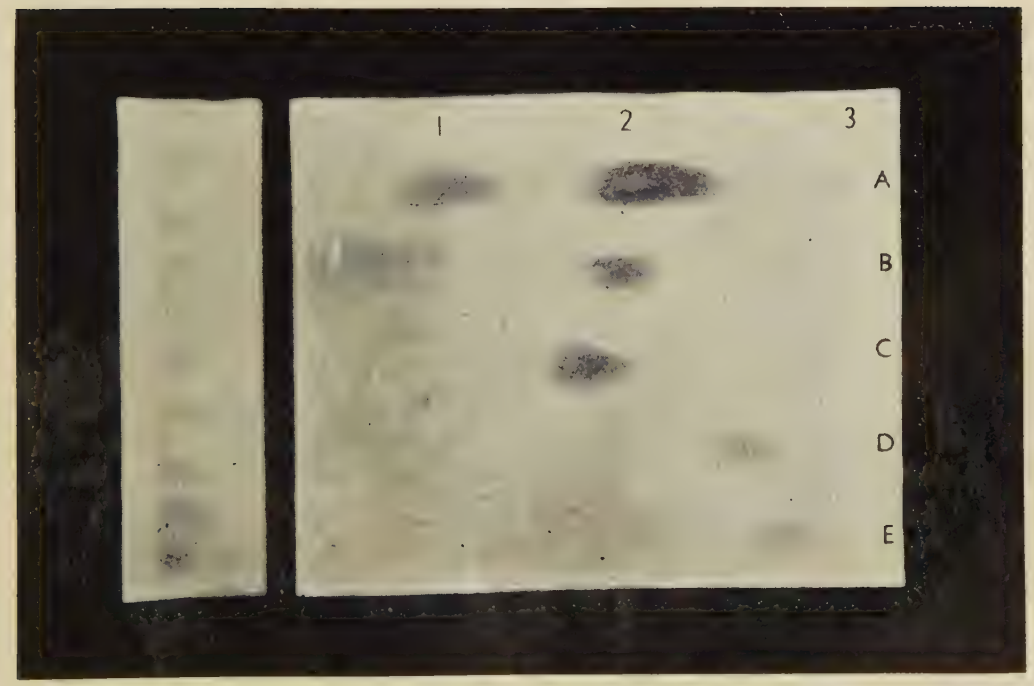


Plate 2. Paper chromatogram of the products of hydrolysis of agar by *Vibrio purpureus* (after 7 days' incubation at 25°C) A: hydrolysate, B: galactose, C: glucose, D: cellobiose, E: lactose

The melting point of these crystals agreeded with that of mucic acid* (212°C). And by addition of these crystals the melting point of mucic acid did not drop.

From the result of this observation the presence of galactose is confirmed in the enzymatic hydrolysate of agar.

2. Paper chromatographic analysis of enzymatic hydrolysate

The apparatus used for the paper chromatography was essentially identical with that described by CONSDEN, GORDON and MARTIN.[13]

Strips of Toyo No. 50 filter paper 11 × 40 cm were employed.

A small quantity (0.01 cc.) of the concentrated hydrolysate and of control sugars (0.1%) were applied with a capillary pipette along a penciled line approximately 6 cm from an end, and at intervals of approximately 1.5 cm. After 24 hours' incubation in a closed vessel, the solvent** had irrigated 23–24 cm of the paper. The paper was removed, dried in an oven at 80°C, sprayed with the developer*** and developed at 100° C for 5–7 minutes.

With the benzidine developer the migrating solute appeared as brown spots, varying in intensity with the concentration of sugars present. After developing the chromatogram, the Rf value of each spot produced by the unknown was compared with those of known sugars. (Plate 2) (Table 2)

Table 2 Rf value of each spot developed on the paper chromatogram of the products of hydrolysis of agar by *Vibrio purpureus*

Sugar	Rf value
Enzymatic hydrolysate of agar spot 1	0.39
Enzymatic hydrolysate of agar spot 2	0.25
Enzymatic hydrolysate of agar spot 3	0.00
Galactose	0.22
Glucose	0.27
Cellobiose	0.12
Lactose	0.09

This chromatogram test indicates that the enzymatic hydrolysate contains a large quantitys of galactose(spot 2)and small quantities of two unknown sugars (spot1 spot 3). One of these did not move from the original spot during the irrigation and the other moved more rapidly on the chromatogram than galactose. They might be either biose triose, tetraose, etc., or uronic acids.

Summary

1. An extracellular enzyme produced by *Vibrio purpureus* rapidly reduced the viscosity of agar and produced galactose as a major end product of hydrolysis of agar.

* Using this method, mucic acid is also formed from galacturonic acid,

** Solvent: n-butyl alcohol, 50 cc,: pyridene, 30 cc, ; distilled water, 10 cc,

*** Horrocks' developer[14] : benzidine, 0.5g. : glacial acetic acid, 20 cc. absolute ethyl alcohol 80cc.

2. The pH optimum of this enzyme was 5.2 to 6.0 and the optimal temperature for it occured between 40–50°C.

This enzyme showed the highest activity when approximately 3 % NaCl existed in the reaction mixture.

3. The process of the formation of reducing sugars from by agar the action of enzyme of *Vibrio purpureus* obeyed the monomolecular reaction with in a certain range.

4. The chromatographic test indicated that the enzymatic hydrolysate contained a large quantity of galactose and small quantities of two unknown sugars.

The author is indebted to professor Masao KIMATA for his kind suggestions in the course of this study.

Literature

1. KADOTA, H., Mem. Coll. Agr. Kyoto Univ., **59**, 54-67(1951)
2. GRAN, H. H. Bergens Museums Aarbog, **2**, 1-16 (1902)
3. AOI, K., and ORIKURA, J., Zentbl. Bakt., IIAbt., **74**, 321-333 (1928)
4. VAN DER LEK J. B., Nederland. Tijdschr. Hyg. Microbiol Serol., **3**, 267-280 (1929)
5. WAKSMAN, S. A., and BAVENDAMM, W., Jour. Bact., **22**, 91-102 (1931)
6. BAVENDAMM. W., Ber. Deut Bot. Gessell., **49**, 288-289 (1931)
7. STANIER. R. Y., Jour Bact., **42**, 527-560 (1641)
8. HUMM H. J., Bull. Duke Univ. Marine Lab., **3**, 45-70 (1946)
9. OSHIMA K., Jour. Agr. Chem. Soc, Japan, **7**, 328-331 (1931)
10. MORI. K., Jour. Agr. Chem Soc. Japan, **15**, 1070-1074 (1939)
11. FUKUMOTO, J. ,and ISHIMATSU, K., Bull. Osaka Municipdl Technical Res. Inst., **13**, 1-10 (1951)
12. ISHIMATSU, K. and KIBESAKI, Y., Symposia on Enz. Chem., **6**, 75 (1950)
13. CONSDEN, R. GORDEN A. H., and MARTIN, A. J. p., Biochem. Jour., **38**, 224 (1944)
14. HORROCKS R. H., Nature, **164**, 444 (1949)

The Phytoplankton of Lake Mikata

By

Yuichi YONEDA*

With 6 Tables and 2 Figures

I. Introduction.

Lake Mikata under consideration is the only fresh-water lake among the Mikata Lake Group, which lie in the western region of Fukui Prefecture at about 35°35′ N. Lat. and 135°55′ E. Long. The Lake Group consists of the following five lakes: Hiruga, Kugushi, Suigetsu, Suga, and Mikata. The location of these lakes with respect to each other is shown in Figure 1. The lakes are all natural bodies of water and a sort of tectonic lake. The terrain is mostly hilly and the drainage area feeding these lakes is small. The northern two lakes–Hiruga, Kugushi–communicate with the sea water of Wakasa Bay on the north by a narrow outlet respectively, and are filled with salt water. The waters of Suigetsu and Suga are not under the direct influence of the sea water, but they are connected with the salt waters of Hiruga and Kugushi by an artificial channel respectively and the waters are brackish in nature. Lastly Lake Mikata, most distant from the sea, is situated to the immediate south of the preceding two lakes, and is characterized by its extremely shallow basin filled with turbid fresh-water. The Mikata Lake Group therefore comprises two salt, two brackish and one fresh-water lakes, and they have excited the immagination of scientists and laymen alike.

The investigation of the Mikata Lakes is to be undertaken from its scientific as well as its economical aspects. It must be an interesting subject to study their flora and fauna with reference to ecological features. The present work was principally been planned as a continuation of the study of the alga-flora, and this preliminary report deals with a consideration of the phytoplankton of Lake Mikata. This report has covered the period of one year, from February in 1951 to January in 1952.

Before the writer leaves this heading he should like to thank his assistant workers, especially Mr. I. UMEZAKI as a most constant companion, and several members of the Maizuru Marine Observatory for their cooperation in sampling. The assistance in the field given by Messrs. MATSUYAMA, UENO, SENDA, and other members of the Torihama Fisheries Agency deserves grateful acknowledgment.

---

*. Botanical Laboratory

Fig. 1. Map of the Mikata Lake Group, showing stations from which data were collected.

II. Natural and Some Limnological Features.

Lake Mikata, often called Kamiko, is essentially a sort of marsh, receiving water through several rivulets and brooks. Paddy fields, covering mostly the southern bank, have probably an important effect upon the water through their contribution of organic matter to the drainage water. The generally flat basin is silted with blackish mud, several metres in thickness. According to the morphometrical results obtained by the late Dr. A. TANAKA and other researchers, it has an area of approximately 3.6 square kilometres and a perimeter of about 10.18 kilometres. The mean depth of the water was recorded as being 1.33 metres, and the greatest depth of 2.4 metres was measured at a short distance off Narude, where lies a spring. But by the present investigation at several stations, the depth gave somewhat greater measurements, ranging from 1.5 metres to 1.8 metres, and the greatest depth of 2.55 metres was found in the neighbourhood of the Seto Channel at Station 10 (Fig. 1.).

Limnological investigations of the lake has hitherto been little published, and it was desirable to carry on acurate researches in the field. But owing to lack of time and other various interferes, it was impossible for the writer to obtain sufficient results. Temperatures, hydrogen-ion concentration and some other conditions were measured in the present investigation. Ten stations, marked in the map (Fig 1), were selected for sampling. The stations were selected so that the locations may be easily found again in the field.

TEMPERATURE. The lake basin of Mikata is situated almost on the boundary line of tropical and temperate lakes of Japan. The temperature of the water has frequently been a little over 30°C in summer and rarely much below 4°C in winter. From the standpoints of the water temperature, the lake is a temperate lake. Owing to the scantiness of available data of the temperature records for the lake, the minimum temperature cannot be determined, but it is certain that in the coldest season the water may be slightly lower than 4°C and it is rare for the lake to be frozen.

The temperature records from February, 1951 to January, 1952 are presented in Table I. The measurements were made mostly during the time from 1.00 to 3.30 p. m. In the months of June, July and August, the summer time was used. In the lake, with shallow basin, the water was subjected to almost complete mixing by winds or other stirring actions, and the temperature did not reflect any established stratification. The temperature difference between the surface and bottom waters was slight throughout the year round. During the winter the water of basin was almost homothermal, considering from the present investigation and also from the data of Mr. T. KAWANA of the Prefectural Laboratory published in 1936. The difference was usually only 0.1°C. But during the summer the water temperature on the surface and that in the bottom showed some difference. The difference was usualy 1–2°C. Moreover, during the summer the water temperatures greatly near the air temperatures,

Table. I. Surface water temperatures, with bottom mud temperatures in brackets, in degrees Centigrade.

Date	St.1	St.2	St.3	St.4	St.5	St.6	St.7	St.8	St.9	St.10	Air temp. & Weather
1951 16/II	3.8	3.8	3.7	3.8	3.6	3.6	3.7	3.6	3.7	3.7	7.2
	(4.0)	(4.1)	(3.8)	(3.9)	(3.8)	(3.8)	(3.9)	(3.8)	(3.9)	(3.9)	Cloudy
23/III	10.3	10.0	—	9.8	—	—	10.4	—	9.8	10.5	10.7
	(10.0)	(9.5)	—	(9.7)	—	—	(9.9)	—	—	—	Cloudy & windy
25/IV	14.5	14.3	15.0	15.0	15.5	15.3	15 0	15.1	15.3	14.9	14.0
	(14.0)	(13.8)	(14.4)	(14.4)	(14.5)	(14.0)	(14.0)	(15.0)	(14 4)	—	Cloudy
27/VI	28.3	28.0	26.0	27.7	28.5	28.0	27.0	28.9	27 0	26.4	29
	(24.0)	(24.2)	(23.7)	(24.5)	(25.1)	(24.8)	(24.6)	(24.3)	(24.5)	—	Cloudy
26/VII	30.7	29.5	32.2	31.6	32.0	29.7	29.7	29.8	30 4	29.7	29.5
	(29.8)	(26.5)	(28.2)	(27.2)	(28.8)	(28 2)	(29.0)	(29.7)	30.2)	—	Clear
30/VIII	30.5	30.8	29.5	31.0	29.5	29.8	29.5	29.6	29.5	30.3	30
	(29.8)	(28.6)	(29.0)	(28.6)	(28.8)	(29.0)	(28.9)	(29.4)	(29.4)	—	Clear
30/IX	22.8	23.2	23.8	23.2	23 8	23.9	23.2	23.3	23.7	23.7	24.9
	(23.0)	(23.0)	(23.2)	(22.3)	(23.0)	(23.7)	(22.9)	(23.2)	(23.9)	—	Clear
29/X	18.5	18.5	18.0	18.3	18.2	18.2	18.5	18.5	18.5	18.0	21.0
	(18.0)	(18.5)	(19.2)	(18.2)	(19.2)	(19.5)	(18.3)	(19.8)	(20.0)	—	Cloudy
29/XI	8.2	8.2	8.2	8.2	8.4	8.2	8.4	8.1	8.1	8.2	13.0
	(8.4)	(8.4)	(8.4)	(8.5)	(8.5)	(8.3)	(8.5)	(8.2)	(8.4)	—	Cloudy & rainy
26/XII	8.1	7.8	8.1	8.0	8.1	8.1	8.2	8.2	8.3	8.2	—
	(8.8)	(8.5)	(9.2)	(8.5)	(9.2)	(9.2)	(8.4)	(9.0)	(9.5)	—	Cloudy
1952 19/I	3.8	3.6*	4.1	3.5*	4.2	—	3.7	4.1	—	4.1	7.8
	(4.8)	(5.3)	(5.2)	(4.6)	(5 0)	—	(4.9)	(5.0)	—	(6.4)	Cloudy

* The results of measurement on Jan. 20.

while during the winter the former were obviously lower than the latter. The seasonal variation of the bottom mud temperatures paralleled usually the water temperatures. During the winter, however, the mud temperatures were slightly higher or almost equal to the water temperatures on the surface. On the other hand, during summer this relation was inverted. For general comparison, mean air temperature at Tsuruga Meteorological Station is tabulated in Table II.

Table II. Mean air temperature, Tsuruga Meteorological Station, in degrees Centigrade.

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Maximum	6.8	7.6	10.6	16.7	21.1	25.2	29.6	31.3	27.2	21.4	15.7	9.9	18.1
Minimum	0.3	0.2	2.5	7.2	12.0	16.9	21.7	22.5	18.4	12.1	7.1	2.9	10.3

HYDROGEN-ION CONCENTRATION. The hydrogen-ion concentration, expressed as a pH value, was determined colorimetrically. The results obtained during the period are given in Table III. As a rule, the reaction of the surface water was neutral or alkaline, and varied between pH 7.0–9.7 during the whole period. During the cold season, the surface water was neutral or weakly alkaline, with little variation (pH 7.0-7.4). During the warmer and hot seasons, the pH values showed a greater alkaline nature, with somewhat broad variation ranging between pH 7.4 and 9.7. Generally, as in the case of the temperature relation, the pH value in the same investigation showed usually very little variation by

stations. The higher values in summer and autumn were corresponding to the abundance of the phytoplankton. The water of the Hasu River, which enters into the lake on the south-east side, was weak acidic or slightly alkaline. By the investigation on February 16, 1951, it showed the pH of 6.4 and on April 25, the pH of 7.0. The amount of fresh water which enters the lake, however, seemed too small to have any appreciable effect upon the hydrogen-ion concentration of the lake.

Table III. Hydrogen-ion concentration (pH) of the surface water.

Date	St.1	St.2	St.3	St.4	St.5	St.6	St.7	St.8	St.9	St.10
1951 16/II	7.1	7.1	7.1	7.1	7.2	7.1	7.1	7.1	7.1	7.1
23/III	7.3	7.4	—	7.4	—	—	7.4	—	7.4	7.4
25/IV	7.4	7.4	7.5	7.5	7.7	7.6	7.7	7.7	7.6	7.7
27/VI	7.4	7.6	7.8	7.6	7.6	8.0	7.4	7.8	7.8	7.3
26/VII	8.4	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
30/VIII	9.6	9.5	9.4	9.6	9.6	9.7	9.6	9.7	9.7	9.7
30/IX	7.4	7.5	8.3	7.6	8.2	7.8	7.4	8.4	8.0	7.8
25/X	8.2	8.2	8.3	7.6	7.6	8.0	7.4	8.2	8.3	8.4
29/XI	7.4	7.5	8.3	7.6	8.2	7.8	7.5	8.4	8.2	7.8
26/XII	7.2	7.3	7.3	7.2	7.3	7.5	7.4	7.4	7.5	7.4
1952 19/I	7.0	7.1	7.1	7.0	7.0	7.0	7.0	7.0	7.1	7.1

DISSOLVED OXYGEN. The dissolved oxygen content of the water, judging from only a few results, was that of eutrophic lakes. The surface samples on February 16, 1951 varied from 7.75 cc per litre to 9.73 cc per litre and were nearly saturated with oxygen (Table IV). According to the results of oxygen analyses of surface samples, made by Mr. I. YAMAMOTO of the Fukui Prefectural Laboratory, the oxygen content varied from 3.52 cc per litre to 6.68 cc per litre on August 27, 1951. Winter increase and summer decrease of oxygen was considered to be the rule in eutrophic lakes.

Table IV. Some results of limnological investigation on February 16, 1951.

	St. 1	St. 2	St. 3	St. 4	St. 5	St. 6	St. 7	St. 8	St. 9	St. 10
Depth (m)	1.6	1.8	1.7	1.5	1.7	1.65	1.7	1.7	1.8	2.55
Time	13.20	15.25	13.55	15.10	13.50	14.00	14.55	14.20	14.30	14.40
Air temp. (°C)	9.0	6.5	9.0	7.0	6.5	7.0	6.2	7.2	7.4	7.0
Surface water temp.	3.8	3.8	3.7	3.8	3.6	3.6	3.7	3.6	3.7	3.7
Bottom water temp.	3.9	3.8	3.6	3.8	3.7	3.7	3.7	3.6	3.8	4.1
Bottom mud temp.	4.0	4.1	3.8	3.9	3.75	3.8	3.9	3.8	3.9	3.9
Cl of surf. water (mg/l)	33.4	—	66.6	55.5	56.2	52.6	40.6	73.4	60.4	76.8
Cl of bottom water	36.0	49.0	64.8	46.8	55.0	47.2	39.4	61.8	53.0	842.6
O_2 content (cc/l) with percentage saturation	9.35 (101)	9.73 (106)	8.88 (96)	9.33 (101)	8.83 (95)	7.75 (84)	8.38 (90)	8.31 (90)	9.67 (105)	7.89 (85)

CHLORINE. The water of the lake showed generally the fresh-water feature in the amount of chlorine. Here we can quote only a few results. In the survey on February 16, 1951, the Cl content of the water showed some variation by different stations ranging from 37.4 mg per litre to 76 8 mg per litre for the surface water. The CI content of the bottom water differed somewhat from that of the surface water, the former being greater than the latter or vice versa. It was impossible to point out any regular tendency as for the Cl content of the water. This was probably due to the shallowness and the intermixing of the water. The communication of the water with the brackish waters of Suigetsu and Suga seemed to give little effect to the salinity of Lake Mikata. By the results of the present investigation, the water of Lake Suga which enters through the Horikiri Canal into Lake Mikata was too small to effect the salinity of the latter. The brackish water of Lake Suigetsu runs through the Seto Channel into Lake Mikata and the Cl content of the water at Station 10 was somewhat greater than that at other stations. Especially the deeper water showed the evident brackish feature owing to the heavier brackish water which lay at the bottom. In the neighbourhood of the mouth of the Hasu River, practically at Station 1, the Cl content was decidedly low as is shown in Table IV. The Cl content of the water of the river was measured to be only 11.2 cc per litre.

The amount of chlorine of the water seemed to be increased in summer when the sea level was somewhat elevated, and the influence of the brackish water of Lake Suigetsu was strengthened. Considering from meagre results of several investigators, it might be expected that some stratification in Cl content would be seen during the summer months.

TRANSPARENCY. The water was so turbid and opaque all the year round that one could not see its bottom in spite of the extreme shallowness. The transparency of the water was measured by means of a Secchi disc only on January 19, 1952. It varied from 1.2 to 1.55 metres. The transparency decreased, of course, accompanied by the increase of phytoplankton content in summer, but the writer had no accurate data of it.

COLOUR. The greenish brown colour of the water in cold season related to the plankton algae and animals. The blue-green colour in summer was contributed by the prodigious quantity of water-blooms, composed mainly of *Microcystis aeruginosa* and several species of *Anabaena*. In both cases the blackish bottom mud might have somewhat prominent effect on the colouration of the water.

HIGHER AQUATIC VEGETATION. Higher aquatics, both the emergent and submerged types, was a somewhat conspicuous feature of the lake. In general the bottom of the lake was covered with a great mass of mud rich in organic materials and the shore had sufficiently mud accumulated in shallow enough water for

appreciable development of rooted aquatics. Especially *Trapa natans* L. was most common in the eastern area of the lake. It grew vigorously in summer and its floating leaves cover the water surface of the bank. Other aquatics were *Potamogeton oxyphyllus* MIQ., *P. perfoliatus* L., *Myriophyllam spicatum* L. var. *muricatum* MAXIM., *Rupia rostellata* KOCH., *Phragmites communis* TRIN., etc. Almost the whole area of the basin might support these aquatic vegetation, but the angling has disturbed their development except near the shore,

III. General Account of the Phytoplankton.

The importance of the study of the plankton has long been recognized and of late years has been somewhat increased from the better recognition of the part which they play in the food-supply of various higher forms of life. But very little attention has been paid by scientists to the plankton of Lake Mikata, especially about the phytoplankton there have been only sporadic notes in the literature. Moreover, the results were rather rough and far from the object of ascertaining the composition of phytoplankton. In 1936, Mr. T. KAWANA of the Fukui Pretectural Laboratory made an account of the Lake Group but no mention of the phytoplankton of Lake Mikata. The first and single reliable account of the plankton of this lake was made by Dr. S. KOKUBO in 1947. But he attached greater importance to the study of Hiruga and Suigetsu, and he collected samples of Mikata only once on September 23, 1943. Thus in his paper accompanied with a brief mention of Lake Mikata, we met a few species of plankton algae including: *Microcystis aeruginosa*, *Anabaena* spp., *Melosira varians*, *Gyrosigma* sp., *Navicula* sp., *Surirella Capronii*.

The writer made a series of plankton collections for the period from February, 1951 to January, 1952 for the object of ascertaining precisely the composition of the phytoplankton and revealing the seasonal variation, etc. To make the description of the phytoplankton comparative, collections were made monthly, with a single exception of May. The abundance of the phytoplankton is a measure of biological productivity, and it may be desirable to develop the collection on a comparison basis and, moreover, to make them quantitative. In the pres nt work, however, the samples were collected at the surface of the water by towing a fine silk-net (60 meshes per cm.) at the ten stations shown in Figure 1. Because of the extreme shallow water, vertical hauls, although tested several times, proved practically of no use. The method of collecting samples precluded any exact quantitative statement of the results. Many of the nannoplankton presumably passed through the net and were not capturd, and only those taken efficiently were considered.

A qualitative analysis of the phytoplankton were made of about 110 samples. It was found that the plankton alga-flora of Lake Mikata comprised some 173 species, made up as follows: *34 Cyanophyceae, 2 Xanthophyceae, 1 Chrysophyceae, 79 Bacillariophycere, 2 Dinophyceae, 5 Euglenophyceae, 3 Chlorophyceae, 15 Zygophyceae.*

The phytoplankton of the lake were made up for the greater part of the four phyla of algae, viz. *Cyanophyceae*, *Bacillariophyceae*, *Chlorophyceae*, *Zygophyceae*. The diatoms were most numerous followed by the greens and then by the blue-greens. The *Zygophyceae* were as a rule somewhat less significant as a composition of the phytoplankton of this lake. The remaining phyla of plankton algae were very poorly represented in the lake.

The monthly change in the number of species were summed up in Table V. The maximum number of species occurred in August, followed by February. The least occurrence was observed iu December. Generally the quantity of the phytoplankton were large in summer and early autumn. The minor number of species found in July did not mean the small quantity. Zooplankton, being left out of consideration in this paper, were also abundant in summer.

Table V. Monthly variation of the number of species among the phyla of plankton algae

	1951 Feb.	Mar.	Apr.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	1952 Jan.
Cyanophyceae	5	6	5	17	9	17	18	8	11	5	7
Chrysophyceae	1	—	1	—	—	—	—	—	—	—	—
Xan hophyceae	1	—	—	1	1	—	1	1	—	—	—
Bacillariophyceae	28	15	23	5	2	21	9	11	9	8	29
Dinophyceae	—	—	1	2	—	—	1	—	—	—	—
Euglenophyceae	1	—	—	1	1	1	3	1	1	1	1
Chlorophyceae	7	2	7	13	10	8	10	3	17	5	4
Zygophyceae	7	7	7	3	4	7	1	3	3	2	6
Total	**50**	**30**	**44**	**42**	**27**	**54**	**43**	**27**	**41**	**21**	**47**

The most prominent role in the plankton population was played by the *Cyanophyceae* in summer and the subordinate role by the *Bacillariophyceae* in winter. The *Chlorophyceae* were less significant in spite of the greater number of species; they occurred only in small quantity, never approaching dominance throughout the whole year. The predominance of the *Bacillariophyceae* and *Cyanophyceae* has been known as a characteristic of silted lakes. The phytoplankton of this lake was further characterized by the rare occurrence of desmids.

The number of species summed up for each station during the whole period were in order of the following (the figures between brackets show the number of species found at each station): St. 1 (145), St. 3 (120), St. 8 (101), St. 9 (93), St. 4 (87), St. 5 (86), St. 2 (82), St. 7 (70), St. 6 (78), St. 10 (61). The greatest number of species at Station 1 was somewhat remarkable. Generally it seemed that southern shores of the water were under more favourable condition for many algae owing to the effect of drainage water, which come from the several rivulets or paddy fields. On the other hand the northern part of the water afforded

less luxuriant development of algae than the southern part. The least number at Station 10 seemed to be on account of the unfavourable condition of the water; the intermixing of the brackish water of Lake Suigetsu with the fresh water of Lake Mikata might be the main cause.

Nevertheless, as for the distribution of the phytoplankton in the lake, it was impossible to point out any considerable characteristic. That is, the plankton algae were as a rule uniformly distributed from station to station in each season. All the important species were found in nearly all samples collected from various stations. The uniform distribution of the phytoplankton was to be attributed to the apporoximately uniform conditions of the water.

A list of species, with seasonal change of occurrence, is presented in Table VI, from which the periodicity of the phytoplankton of this lake can be ascertained to some extent.

Table VI. Phytoplankton identified in each month during the period.

	1951 Feb.	Mar.	Apr.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	1952 Jan.
Cyanophyceae											
Chroococcales											
Microcystis aeruginosa	r	rr	rr	c	a	aa	a	c	c	r	r
M. incerta	—	—	—	—	—	o	o	—	—	—	rr
Aphanocapsa elachista	rr	r	rr	r	r	r	o	o	o	r	rr
A. delicatissima	—	—	—	r	o	—	o	r	—	—	—
A. Grevilleii	—	—	—	r	—	—	—	—	—	—	—
A. pulchra	—	—	r	—	—	—	—	—	—	—	—
Aphanothece nidulans	—	r	—	—	—	—	—	—	—	—	—
A. nidulans v. *endophytica*	—	—	—	—	—	—	o	—	—	—	—
A. microscopica	—	—	—	—	—	r	—	—	—	—	—
Gloeothece linearis	—	—	—	—	—	—	—	—	r	—	—
Chroococcus turgidus	—	—	—	—	—	r	—	—	r	—	—
C. minutus	—	r	rr	r	—	r	r	—	o	r	rr
C. minimus	o	—	—	—	—	—	—	—	r	—	—
C. dispersus	—	—	—	—	—	—	—	—	r	—	—
Coelosphaerium dubium	—	—	—	—	—	—	—	—	—	r	rr
C. Kuetzingianum	r	—	—	o	r	r	r	—	—	—	—
Gomphosphaeria aponina	—	—	—	—	—	—	—	—	rr	—	—
G. lacustris	—	—	—	—	—	—	rr	r	—	—	—
Merismopedia punctata	—	—	—	r	r	r	c	o	o	o	—
M. tenuissima	—	—	—	rr	—	—	—	r	—	—	—
Dactylococcopsis irregularis	—	r	—	r	—	o	r	r	r	—	rr
Nostocales											
Raphidiopsis mediterranea fo.	—	—	—	—	—	—	c	—	—	—	—
Anabaena flos-aquae	—	—	—	—	—	o	—	—	—	—	—
A. catenula v. *affinis*	—	—	—	o	c	c	o	—	—	—	—
A. Scheremetievi v. *recta* fo.	—	rr	c	a	c	—	o	—	rr	—	—
A. spiroides	—	—	—	rr	r	c	o	—	—	—	—
Spirulina major	—	—	—	rr	—	—	—	—	—	—	—
Oscillatoria limosa	rr	—	—	—	—	—	—	—	—	—	rr
O. tenuis	—	—	—	r	—	—	o	—	—	—	—
O. animalis	—	—	—	rr	—	rr	rr	—	—	—	—
O. brevis	—	—	—	rr	—	o	rr	—	—	—	—
O. formosa	—	—	—	—	—	rr	—	—	—	—	—
Phormidium mucicola	—	—	—	—	—	o	—	—	—	—	—
Lyngbya limnetica	—	—	—	o	c	aa	c	c	—	—	—

Table VI (continued).

	1951 Feb.	Mar.	Apr.	June	July.	Aug.	Sept.	Oct.	Nov.	1952 Dec.	Jan.
Chrysophyceae											
Dinobryon sertularia	r	—	o	—	—	—	—	—	—	—	—
Xanthophyceae											
Chlorobotrys regularia	rr	—	—	rr	rr	—	—	—	—	—	—
C. limnetica	—	—	—	—	—	—	rr	rr	—	—	—
Bacillariophyceae											
Centrales											
Melosira Juergensi	o	o	r	—	—	—	—	—	—	—	—
M varians	—	r	r	r	rr	rr	—	—	r	r	r
M. americana	rr	—	—	—	—	—	—	—	—	—	—
Cyclotella Kuetzingiana	—	—	—	—	—	rr	—	—	—	—	r
C. Meneghiniana	rr	r	c	—	—	—	—	—	rr	—	rr
C. comta	—	—	—	—	—	rr	rr	—	—	—	—
Coscinodiscus lacustris	—	—	o	—	—	—	—	—	—	—	—
Pennales											
Fragilaria capucina	—	—	—	—	—	—	—	rr	—	—	rr
F. construens v. *subsalina*	—	—	—	—	—	rr	—	—	—	—	—
Asterionella gracillima	r	—	—	—	—	—	—	—	—	—	—
Synedra ulna	o	rr	rr	rr	—	o	o	r	—	rr	rr
S. ulna v. *biceps*	rr	rr	—	—	—	—	—	—	—	—	—
S. japonica	r	—	—	—	—	—	—	—	—	—	—
S. acus	a	a	aa	—	—	—	rr	r	r	—	o
S. acus v. *radians*	—	a	c	—	—	—	—	—	—	—	—
S rumpens	—	r	r	—	—	—	—	—	—	—	—
S. affinis v. *fasciculata*	—	rr	—	—	—	—	—	—	—	—	—
Achnanthes breviceps	—	—	—	—	—	—	rr	r	—	—	—
Frustulia rhomboides v. *saxonica*	—	rr	—	—	—	—	—	—	—	—	r
Gyrosigma Kuetzingii	—	—	—	—	—	rr	—	—	—	—	—
N. eidium affine	—	—	—	—	—	—	—	—	—	—	r
N.. productum	—	—	—	rr	—	—	—	—	—	—	—
Diploneis ovalis	—	—	—	—	—	rr	—	—	—	—	r
D ovalis v. *oblongella*	o	—	—	—	—	r	r	r	r	r	o
D puella	c	o	o	—	rr	rr	r	r	r	—	—
Stauroneis anceps	—	—	o	—	—	r	—	—	—	—	rr
Navicula cuspidata	—	—	—	—	—	rr	—	—	—	—	—
N. halophila	—	—	—	—	—	—	—	—	—	—	rr
N. crucicula	rr	—	—	—	—	—	—	—	rr	—	—
N. protracta	—	—	—	—	—	—	—	—	—	—	rr
N. salinarum	—	—	—	—	—	rr	—	—	—	—	—
N. viridula	rr	—	—	—	—	—	—	—	—	—	—
N. placentula f. *rostrata*	—	—	—	—	—	r	—	—	—	—	—
N. Perrotettii	—	—	—	r	—	r	—	—	—	—	—
Pinnularia Tabellaria	—	—	—	—	—	r	—	—	—	—	rr
P. gibba v. *mesogongyla*	—	—	—	—	—	rr	—	—	—	—	—
P. viridis	—	—	—	rr	—	rr	—	—	—	—	—
Tropidoneis semistriata	—	—	—	—	—	—	—	rr	—	—	—
Amphora ovalis	—	—	—	—	—	—	—	—	—	—	rr
A. ovalis v. *pediculus*	—	—	rr	—	—	—	—	—	—	—	rr
A. veneta	—	—	r	—	—	—	—	—	r	—	—
Cymbella turgida	—	—	—	—	—	—	—	—	—	—	rr
C. ventricosa	—	—	o	—	—	—	—	—	—	r	r
C. helvetica	r	r	—	—	—	—	—	—	—	—	—
C. tumida	—	—	—	—	—	—	—	—	—	—	rr
Gomphonema parvulm	r	—	—	—	—	—	—	r	—	r	r
G. acuminatum v. *turris*	r	o	—	—	—	—	—	—	—	rr	r
G. angustatum	—	—	—	—	—	r	—	—	—	—	o
G. longiceps v. *subclavata*	—	—	—	—	—	rr	—	—	—	—	—
G. olivaceum	r	—	—	—	—	—	—	—	—	—	—
Epithemia zebra v. *saxonica*	—	—	—	—	—	—	—	—	r	—	—
E turgida	—	—	—	—	—	r	—	—	r	—	—
Rhopalodia parallela	—	—	—	—	—	r	—	—	—	—	—

Table VI (continued).

	1951 Feb.	Mar.	Apr.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	1952 Jan.
R. gibberula v. *producta*	—	—	r	—	—	—	—	—	—	—	—
Hantzschia amphioxys	—	—	—	—	—	—	—	—	—	—	r
Bacillaria paradoxa	—	—	c	—	—	—	—	—	—	—	r
Nitzschia tryblionella	—	r	o	—	—	—	—	—	rr	—	—
N. tryblionella v. *victoriae*	rr	rr	o	—	—	—	r	—	—	—	o
N. hungarica	r	—	r	—	—	—	—	—	—	—	—
N angustata v. *acuta*	—	—	—	—	—	—	—	r	—	—	o
N. commutata	—	—	—	—	—	—	—	—	—	r	—
N. vivax	—	—	—	—	—	r	—	—	—	—	—
N. capitellata	o	—	—	—	—	—	—	—	—	r	r
N. frustulum	r	—	—	—	—	—	—	—	—	—	—
N. Kuetzingiana	r	—	—	—	—	—	—	—	—	—	—
N. gracilis	r	—	—	—	—	—	—	—	—	r	—
N. palea	o	—	—	—	—	—	—	—	—	—	—
N. vermicularis	r	—	—	—	—	—	—	—	—	—	—
N. sigma	r	—	—	—	—	—	—	r	—	—	r
N. filiformis	—	—	r	—	—	—	r	rr	—	—	—
N. Lorenziana	—	—	r	—	—	—	—	—	—	—	—
N. acicularis	—	—	—	—	rr	—	—	—	—	—	—
N. obtusa	—	—	—	—	—	—	—	—	—	—	r
Cymatopleura solea v. *regula*	rr	—	—	—	—	—	—	—	—	—	—
Surirella biseriata	—	—	—	—	—	—	r	—	—	—	—
S. tenera	—	—	r	r	—	—	—	—	—	—	—
S. robusta v. *splendida*	r	—	o	—	—	—	—	—	—	—	o
S. ovalis	—	—	r	—	—	—	—	—	—	—	—
Dinophyceae											
Glenodinium cinctum	—	—	—	rr	—	—	o	—	—	—	—
Peridinium munusculum	—	—	rr	rr	—	—	—	—	—	—	—
Euglenophyceae											
Euglena acus	—	—	—	r	—	—	—	—	—	—	—
Trachelomonas intermedia	—	—	—	—	—	—	rr	—	—	—	—
T. intermedia v. *elegans*	—	—	—	—	—	r	—	—	—	r	—
T. hispida	—	—	—	—	r	—	r	r	—	—	—
T. volvocina	—	—	—	r	—	—	c	—	r	—	o
Chlorophyceae											
Volvocales											
Gonium pectorale	—	—	—	—	—	—	—	—	o	r	—
Eudorina elegans	—	—	—	—	—	—	—	—	r	—	r
Tetrasporales											
Gloeocystis gigas	—	—	r	—	r	—	—	—	o	—	—
Sphaerocystis Schroeteri	—	—	—	r	r	r	—	—	—	—	—
Asterococcus superbus	—	—	—	—	—	r	—	—	—	—	—
Chlorococcales											
Tetraedron minimum	—	—	—	r	o	—	—	—	—	—	—
T. pentaedricum	—	—	—	r	—	—	—	—	—	—	—
T. trigonum	—	—	—	—	—	—	r	r	—	—	—
Golenkinia paucispina	—	—	—	—	—	—	r	—	—	—	—
Oocystis Borgei	r	r	—	—	r	—	—	—	—	—	—
Lagerheimia subsalsa	—	—	—	—	—	—	—	—	r	—	—
Ankistrodesmus falcatus	o	—	r	—	—	r	—	—	o	—	r
A. falcatus v. *acicularis*	—	—	—	—	—	—	o	—	—	—	—
A. falcatus v. *mirabilis*	—	—	—	—	—	—	r	—	r	—	—
A. setigerus	—	—	—	—	—	—	r	—	—	r	—
A. spiralis	—	—	—	—	—	—	—	—	r	—	—
Selenastrum Westii	—	—	—	r	—	—	—	—	—	—	—
Dictyosphaerium Ehrenbergianum	o	—	—	o	r	—	—	—	o	—	—
Westella botryoides	—	—	—	rr	o	—	—	—	o	—	—
Pediastrum Boryanum	—	—	—	r	—	—	—	—	—	—	—
P. duplex	—	—	r	—	—	—	—	—	o	—	rr
P. tetras	—	—	—	r	—	—	—	—	—	—	—
Sorastrum americanum	—	—	—	—	—	—	r	—	r	—	—

Table VI (continued).

	1951 Feb.	Mar.	Apr.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	1952 Jan.
Crucigenia crucifera	—	—	—	—	—	—	—	—	r	—	—
Scenedesmus obliquus	—	—	—	rr	—	o	—	—	—	—	—
S. acuminatus	—	—	—	rr	r	r	o	—	r	r	—
S. bijugatus	—	—	r	r	o	c	—	rr	r	r	—
S. bijugatus v. *alternans*	—	—	—	—	—	—	—	—	rr	—	—
S. quadricauda	r	r	r	o	r	r	r	r	o	r	rr
Coelastrum microporum	—	—	r	r	r	r	—	—	o	—	—
C. proboscideum	—	—	—	—	—	—	r	—	—	—	—
Ulotrichales											
Ulothrix subtilissima	r	—	r	—	—	—	—	—	—	—	—
Chaetophorales											
Aphanochaete hyalothecae	r	—	—	—	—	—	—	—	—	—	—
Stigeoclonium sp.	r	—	—	—	—	—	—	—	—	—	—
Oedogoniales											
Oedogonium stellatum	—	—	—	—	—	—	r	—	—	—	—
Zygophyceae											
Desmidiales											
Closterium rostratum	—	—	—	—	—	r	—	—	—	—	—
C. gracile v. *elongatum*	—	—	o	—	—	—	—	—	—	—	—
Cosmarium pygmaeum	—	—	—	r	o	r	—	—	—	—	—
C. tenue	—	—	—	—	r	r	r	—	—	—	—
C. Blyttii	—	—	—	—	—	r	—	—	r	—	—
Staurastrum tetracerum	r	r	r	o	o	r	—	—	c	—	—
S. gracile v. *nanum*	—	—	—	—	r	—	—	—	—	—	—
Sphaerozosma excavatum	—	—	—	o	—	—	—	—	—	—	—
Hyalotheca dissiliens	o	r	r	—	—	—	—	—	—	—	r
Zygnematales											
Mougeotia viridis	—	—	o	—	—	—	—	—	—	—	o
Mougeotia sp.	c	o	—	—	—	r	—	—	—	—	r
Zygnema sp.	o	r	—	—	—	—	—	—	—	—	—
Spirogyra nitida	o	o	c	—	—	—	—	—	—	—	—
S. communis	a	a	a	—	—	—	—	—	—	o	c
Spirogyra sp.	o	o	r	—	—	r	—	—	—	—	o

The limited number of the characteristic species in this lake has probably come from the relatively stable condition of the water. The dominant species varied in the course of the seasons. During hot season, *Microcystis aeruginosa* has attained its prodigious propagation to form a marked water-bloom. During the winter and early spring, several species of *Spirogyra* were most abundant, but abruptly disappeared in warmer season. The diatom, *Synedra acus* and its variety, was also abundantly observed in winter.

The abundant species were occasionally found to be constant, though this was not necessary always the case. *Microcystis aeruginosa* occurred throughout the whole year, although very few in cold seasons. Some species appeared abundantly for a rather short period when the lake conditions were favourable to them, and abruptly disappeared. *Lyngbya limnetica*, for example, was commonly observed from June to October, the maximum occurrence being in August.

Several species were observed constantly but in small quantity throughout the year. For example, *Aphanocapsa elachista* appeared in nearly all samples collected in each month, but never attained to abundant propagation. *Synedra ulna*, *Diploneis puella* were also considered to be annual constants, although they were not present during a short period. A number of species occurred constantly in nearly all samples for a very short period. These temporary constant species were abundant or small in quantity. A new form of *Raphidiopsis mediterranea* was observed only in samples collected in September. It was generally distributed in this lake but scattered.

It was a fairly obvious fact that some species were constantly occurring together and forming associations. In some cases the associated species belonged to the same or allied genus, and in other cases they were widely different phyla of algae. These associations were most easily recognized among the dominant species. For example, *Spirogyra communis* was dominant in winter and it was always associated with other species of *Spirogyra*, *Zygnema*, and *Mougeotia*. During the summer, several species of *Anabaena*, of which *A. Scheremetievi* var. *recta* f. *ovalispora* was the dominant, were frequently observed intermingled together. The *Spirogyra* association contained always *Synedra acus* and its variety as constant composition. And the *Anabaena* association was found accompanied with abundant masses of *Microcysits aeruginosa*.

The special relation between the epiphytes and their host plankton algae were interesting. *Phormidium mucicola*, *Aphanothece nidulaus* v. *endophytica* were occasionally observed growing in the mucilage of *Microcystis aeruginosa*. *Aphanochaete hyalothecae* was observed but rarely on the filaments of *Hyalotheca dissiliens*.

A greater number of species observed were of fresh-water origin, but a considerable number of brackish forms were also found. The brackish forms were mostly recognized among the diatoms, which are known as a rule to be quite sensitive to changes of the salt contents. They were as follows: *Melosira Juergensi*, *Cyclotella Kuetzingiana*, *C. Meneghiniana*, *Coscinodiscus lacustris*, *Fragilaria construens* v. *subsalina*, *Synedra affinis* v. *pauciculata*, *Achnanthes brevipes*, *Diploneis ovalis*, *Navicula protracta*, *N. halophila*, *N. salinarum*, *N crucicula*, *N. Perrotettii*, *Gomphonema olivaceum*, *Tropidoneis semistriata*, *Epithemia turgida*, *Bacillaria paradoxa*, *Nitzschia tryblionella*, *N. hungarica*, *N. commutata*, *N. vivax*, *N. capitellata*, *N. frustulum*, *N. sigma*, *N. obtusa*. These species, however, have occasionally been reported from fresh-water alike. The blue-greens have generally a wide adaptability to changes of conditions and a number of species which are essentially fresh-water forms have been reported from brackish waters of various districts. In the present work such forms were as follows: *Microcystis aeruginosa*, *Chroococcns minutus*, *Gomphosphaeria aponina*, *Coelosphaerium dubium*, *Merismopedia tenuissima*, *Oscillatoria tenuis*. Among the greens, *Lagerheimia subsalsa* was the only brackish representative. These brackish forms showed no regular tendency in distribution, that is, they were occurring scattered in the whole area of the lake. The *Zygophyceae* is a phylum containing almost exclu-

sive'y fresh-water species. In the phytoplankton of Lake Mikata, it was a particular feature that their relatively frequent occurrence were observed in winter when the salinity was rather low, and they decreased in summer.

A certain species of diatoms were believed to be tropical elements. They were as follows : *Melosira americana, Cymbella turgida, Navicula Perrotettii.* These species, however, have occasionally been reported from temperate waters of Japan.

It was an outstanding fact that no species new to science was actually found in this lake, in spite of the great number of species observed. *Raphidiopsis mediterranea* SKUJA forma *major* YONEDA was the single form recorded as new in this paper.

IV. Some Remarks on Noteworthy Species.

In our country systematic research has not yet attained its ultimate goals, especially for phytoplankton, and in this section some brief notes on noteworthy species will be given.

CYANOPHYCEAE

The *Cyanophyceae* were most abundant in summer and early autumn, decreased gradually towards the colder seasons. The algae responsible for the water-blooms were chiefly *Microcystis aeruginosa* and several species of *Anabaena*, especially *A. Scheremetievi* v. *recta* f. *ovalispora.* Other important species of the phytoplankton were *Aphanocapsa elachista, Chroococcus minutus, Merismopedia punctata* and *Lyngbya limnetica.* But these minute forms, as a matter of fact, never attained high productivity. Some species appeared throughout the whole year round, but the abundant occurrence was observed only in hot season. A sudden increase in quantity was seen in June and a sudden decrease in October.

Microcystis aeruginosa KUETZ.; GEITLER, Cyanophyceae in RABENH., Kryptogamenfl. 14, p. 137, f. 59 d, 1930; YONEDA, Cyanophyceae of Japan I, p. 180, f. 2, 1937 ; HUBER-PESTALOZZI, Phytopl. Süssw. 1, p. 132, Abb. 4 & 4A, 1938; DROUET and DAILY, Plankt. Freshw. Species of *Microcystis*, Field Mus. Nat. Hist. Bot. 20, p. 74, 1939. Syn. *Clathrocystis aeruginosa* (KUETZ.) HENFREY.

This species was observed regularly and constantly in nearly all samples collected in each month. Its predominance occurred in August and September, forming water-bloom. In very heavy water-blooms compact masses of several centimetres in thickness were found, with individual cells agglutinated and the gelatinous envelope of each colony confluent with that of neighbouring colonies. When copious water-blooms were not seen, the predominance of spherical colonies occurred. They had the character of *Microcystis flos-aquae* (WITTR.) KIRCHN. Several workers have been of the opinion that these two species are the same one. This species has

often been reported from brackish waters. Cells were usually 4–5μ in diameter, containg gas-vacuoles. Euplankton.

Aphanocapsa elachista W. et G. S. WEST, Journ. Linn. Soc. Bot. 30 p. 275, t. 15, f. 9, 10, 1894; GEITLER, l. c. p. 156, f. 69 b; HUBER-PESTAL., l. c. p. 138, f. 7.

The alga was observed constantly throughout the year but in small quantity, excepting somewhat abundant occurrence during the period from September to November. Cells small, ca. 1.5μ in diameter, forming small colonies of 14–40μ in diameter.

Aphanocapsa delicatissima W. et G. S. WEST, Journ. Linn. Soc. Bot. 40. p. 431, pl. 19, f. 2–3, 1912; GEITLER, l. c. p. 157, f, 69 c, d; HUBER-PESTAL., l. c. p. 138, f. 11.

It was observed in several samples collected from June to October, but in small quantity. Cells very small, 0.75μ in diameter; colonies small, 15–25μ in diameter.

Aphanothece nidulans P. RICHT. var. *endophytica* W. et G. S. WEST, Journ. Linn. Soc. Bot. 40, p. 432, pl. 19, f. 14, 1912; GEITLER, l. c. p. 169.

It was observed in two samples collected at stations 1 and 2 in September. Cells embedded in gelatinous envelope of *Microcystis aeruginosa*, and the colonial envelope was usually confluent with that of the host alga.

Chroococcus minutus (KUETZ) NAEG.; GEITLER, l. c. p. 232, f. 112a, 113c; YONEDA, Cyan. Jap. I, p, 188, f. 15, 1937; HUBER-PESTAL., l. c. p. 147, f. 30.

It appeared nearly in all samples collected during the whole period, but usually in small quantity. Somewhat abundant occurrence was in November.

Coelosphaerium Kuetzingianum NAEG.; GEITLER, l. c. p. 253, f. 121 c, d; YONEDA, Cyan. Jap. I. p. 190, f, 19, 1937; HUBER-PESTAL., l. c. p. 154, f. 44.

It appeared in several samples collected in February, June, August, and September, but always in small quantity. The gelatinous sheath of this alga was generally so delicate that it was often difficult to demonstrate its presence. Facultative plankton. Cells 2–3μ in diameter, colonies 20–35μ.

Merismopedia punctata MEYEN; GEITLER, l. c. p. 263, f. 129c; YONEDA, Cyan. Jap. I, p. 190, f. 20, 1937; HUBER-PESTAL., l. c. p. 160, f. 58.

This species appeared constantly in many samples collected from June to December. Somewhat common occurrence was observed in September, but usually it occurred in small quantity. Tychoplankton. Colonies 16–64–celled.

Raphidiopsis mediterranea SKUJA forma *major* YONEDA, nov. fo.

Filaments free-floating, mostly short, 85–314μ in length, straight or more or less

Fig.2. *Raphidiopsis mediterranea* SKUJA forma *major* YONEDA, nov. fo. (×1000)

flexuous, tapering towards both ends or one end after division, trichomes not or hardly constricted at the cross walls, 1.5–3μ in diameter. Cells usually 2 times longer than broad, becoming longer to tapering ends; protoplasm with a few gas-vacuoles, very pale blue-green. Resting cells cylindrical in mature, oblong-ellipsoidal in juvenile stage, single or in twos, 4.5–6.0μ in diameter, 7–19μ in length. —Figure 2.

The present alga was quite close to the species described by SKUJA, differing chiefly from it in having greater size. The proper species has been reported only from Lake Kastoria in Greece.

It appeared almost in all samples collected in September but in relatively small quantity. The sequence of its propagation has seemed to be limited. Euplankton.

To satisfy the International Rules of Botanical Nomenclature, the short diagnosis is given below.

Raphidiopsis mediterranea SKUJA forma *major* YONEDA, nov. fo. Trichomata solitaria, planctonica, plerumque recta vel leviter flexuosa, 85–314μ longa, dissepimentis haud vel vix constrictis, 1.5–3μ crassis, apice attenuata; cellulis cylindraceis, 2-plo longioribus quam latioribus, in pilo usque ad 10-plo longioribus (–12μ); protoplasmate pallidissime aeruginoso, vacuolis praebentibus; sporis singulis vel raro binis, intercalaribus, fere cylindraceis, juvenilibus longe-ellipsoideis, 4.5–6.0μ crassis, 7–19μ longis.

Hab.—In lacu Mikata, Hondo.

Anabaena flos-aquae (LYNGB) BREB; GEITLER, l. c. p. 890, f. 571a, b, 1932; HUBER-PESTAL., l. c. p. 213, f. 133.

It appeared in several samples collected in August, but it was not so abundant as to form water-bloom. The short period of growth was remarkable compared with other species of *Anabaena* in this lake. Euplankton. Cells about 5.5μ in diameter; resting cells common, 8.5-12μ in diameter, 20-26μ in length.

Anabaena catenula (KUETZ.) BORN. et FLAH. var. *affinis* (LEMM.) GEITLER; HUBER-PESTAL., l. c. p. 216, f. 139. Syn. *Anabaena affinis* LEMM.

It appeared in nearly all collections from June to September. It was one of the most abundant species of *Anabaena* next to *Anabaena Scheremetievi* v. *recta* f. *ovalispora*. The predominance was observed in July and August, and it was responsible for water-blooms, accompanied with *Microcystis aeruginosa*. Facultative plankton. Trichomes 6μ in diameter; heterocysts a little larger than the vegetative cells; resting cells common in the samples collected in July and August, 11.5–14μ in diameter, 12–17μ in length.

Anabaena Scheremetievi ELENK. var. *recta* ELENK. f. *ovalispora* ELENK.; HUBER-PESTAL., l. c. p. 207, f. 116.

This was the most abundant of the blue-greens next to *Microcystis aeruginosa*. It appeared first in March but the samples were lacking in resting cells. In the samples collected in April, resting cells were occasional, and in June they were abundantly observed. The species was almost constantly observed from March to July, but it abruptly disappeared in August, and then reappeared in September. Scattered ovoid cells found in August might be the resting cells of this species. The predominance was seen in June as a constituent of the water-bloom,

Anabaena spiroides KLEB.; GEITLER, l. c. p. 881, 1932; HUBER-PESTAL., l. c. p. 208, f. 119.

It was found constantly from June to September, its abundance being in August. Euplankton. Trichomes 6–7.5μ in diameter; heterocysts about 7μ in diameter; resting cells 10–13μ in diameter, 12–16μ in length. The breadth of windings usually 50–65μ, the distance between two windings 20–43μ.

Phormidium mucicola NAUMANN et HUBER-PESTALOZZI; HUBER-PESTAL., l. c. p. 244, f. 198.

It appeared in two samples collected in August, but in small quantity. The plant was found as an epiphyte on *Microcystis aeruginosa*.

Lyngbya limnetica LEMM.; HUBER-PESTAL., l. c. p. 248, f. 207.

This minute filamentous blue-green appeared quite regularly in nearly all collections made during the period from June to October. The predominance was observed in August, and then gradually decreased in quantity. Cells 1.2–1.3μ in diameter, 4–6μ in length.

CHRYSOPHYCEAE

Dinobryon sertularia EHRB.; G. M. SMITH, Wisconsin Phytoplankton p. 74, pl. 13, f. 13, pl. 14, f. 1, 1920.

It was observed in collections made in February and April. In samples of

April, encysted individuals were frequently encountered. The alga occurred sparsely intermingled among other algae.

XANTHOPHYCEAE

Chlorobotrys regularis (W. WEST) BOHLIN ; PASCHER, Süssw.-fl. 11. p. 49, f. 30 A-E, 1925.

It appeared in samples collected in February, June and July. Cells 9–10μ in diameter ; colonies ca. 30μ in diameter.

BACILLARIOPHYCEAE

Among the common types of phytoplankton, Lake Mikata possesed a large proportion of the diatoms. The diatoms contributed more species qualitatively than any other phyla of phytoplankton, but quantitatively they were less significant for the greater part of the year. The diatoms were present in nearly all samples except for the collections made in July. The abundant occurrence was observed in winter and the abrupt decrease occurred in early summer. However, the occurrence of numerous species in August was a remarkable phenomenum, although the quantity was small and playing a minor role as plankton. During the winter they were abundant both in the number of species and also in quantity. The diatom-flora was in greater part represented by various species of *Melosira*, *Cyclotella*, *Synedra*, *Navicula*, *Cymbella*, *Gomphonema* and *Nitzschia*. A good number of species of *Nitzschia* were observed in winter but in small quantity. *Surirella Capronii*, reported by KOKUBO in 1947, was not observed in the present investigation.

Melosira Juergensi C. A. Ag. ; HUSTEDT, Bacillariophyta in PASCHER, Süssw.-fl. 10, p. 84, f. 24 & 40, 1930.

It was observed in several samples collected during the period from February to April but in small quantity. Brackish water form. Little known in Japan.

Melosira varians C. A. AG. ; HUSTEDT, l. c. p. 85, f. 41.

It was observed in nearly all samples collected in March, April (1951) and also in January (1952). The species is widely and commonly distributed in various fresh-water circles, especially abundant in eutrophic lakes.

Melosira americana KUETZ. ; HUSTEDT, Bacill. a. d. Aokikosee in Japan. p. 155, pl. 5, f. 8, 1927 ; SKVORTZOW, Diatoms from Kizaki Lake, p. 12, pl. 1, f. 1, 1936.

It appeared in a single collection made in February. The species was first described by KUETZING from tropical America in 1865. In Japan it was found by HUSTEDT in Aokiko, and by SKVORTZOW in Kizaki Lake, Nagano Prefecture.

Cyclotella Meneghiniana KUETZ. ; HUSTEDT, l. c. p. 100, f. 67 ; OKUNO, Notes on

Diatoms of Japan I. p. 37, f. 1, 1940.

It was found occasionally in samples collected in several months. Facultative plankton, usually occurring as a littoral form, occasionally halophilous.

Asterionella gracillima (HANTZSCH) HEIBERG; HUSTEDT, l. c. p. 147, f. 157.

It appeared only in one sample collected in February. This species is known as one of the most common plankton diatoms but in the present survey it was found rarely.

Synedra ulna (NITZSCH) EHRB.; HUSTEDT, l. c. p. 151, f. 158, 159.

It was regularly observed in nearly all samples, excepting collections in July and October. Var. *biceps* (KG.) v. SCHOENF. was found in February and March.

Synedra japonica MEISTER, Beitr. z. Bacill. Japans, p, 307, f. 5, 6. 1913; SKVORTZOW, Diatoms from Kizaki Lake, p. 20. pl. 1, f. 27, pl. 10, f. 9, 1936.

It was observed in collections made in February. This is an endemic diatom to Japan, known fron Suwa and Kizaki Lake, Nagano Prefect.

Synedra acus KUETZ.; HUSTEDT, l. c. p. 155, f. 170.

The species contributed the greatest percentage of diatoms during the winter and spring. Its predominance occurred in April, but disappeared during the summer.

Synedra rumpens KUETZ.; HUSTEDT, l. c. p. 156, f. 175; OKUNO, Notes on Diatoms of Jap. I. p. 42, f. 8, 1940.

It appeared in several collections made in spring.

Achnanthes brevipes AG.; HUSTEDT, l. c. p. 210, f. 308a.

It was observed in two collections made in September and October. This was one of the most characteristic species of the genus; it is essentially a salt water form, but often occurring in brackish water.

Diploneis puella (SCHUMANN) CLEVE; HUSTEDT, l. c. p. 250, f. 394; SKVORTZOW, Diatoms from Kizaki Lake, p. 31, pl. 2, f. 2, 1936.

It was somewhat regularly observed in nearly all samples, but in small quantity.

Navicula Perrotettii GRUN.; CLEVE, Synop. Nav. Diat. 1, p. 110, pl. 3, f. 12, 1894; SKVORTZOW, Neogene Diatoms from Wamura, p. 144, pl. 5, f. 2, 1937.

This characteristic diatom was observed in two samples collected in June and August. The species has been repotted from slightly brackish water in tropical and subtropical regions. Frustules 34–37μ in breadth, 135–180μ in length.

Tropidoneis semistriata (GRUN.) CLEVE; OKUNO, Notes on Diatoms of Jap. II, p. 30, f. 25, 1942. Syn. *Amphiprora semistriata* GRUN.

It appeared only in one collection made in October, and in small quantity. Brackish water form.

Gomphonema acuminatum EHRB. var. *turris* (EHRB.) CIEVE ; HUSTEDT, l. c. p. 372, f. 687.

It was observed in several collections made in February, March and December.

Bacillaria paradoxa GMELIN ; HUSTEDT, l. c. p. 396, f. 755.

It appeared only in two samples collected in April (1951) and also in one sample in January (1952). This is an euryhalinous species. Frustules 5-6μ in breadth, 68–100μ in length. Generally distributed in our country.

Nitzschia tryblionella HANTZSCH ; HUSTEDT, l. c. p. 399, f. 757.

It appeared in several collections made in March, April and in one sample in November. It is known usually as a brackish form, but occasionally occurring in fresh-water.

Nitzschia tryblionella var. *victoriae* GRUN. ; HUSTEDT, l. c. p. 399, f. 758.

It appeared in several collections made in February, March, April, September (1951) and also in January (1952), often accompanied with the proper species.

Surirella robusta EHRB. var. *splendida* (EHRB.) VAN HEURCK ; HUSTEDT, l. c. p. 437, f. 851-852.

It was observed in several samples collected in winter and in April. The species has usually been found growing on bottom mud.

EUGLENOPHYCEAE

Trachelomonas volvocina EHRB. ; LEMMERMANN in PASCHER, Süssw.-fl. 2, p. 145, f. 246, 1913.

It appeared in several collections made in June, September, November (1951) and January (1952). It was the most frequent among the species of *Trachelomonas*.

CHLOROPHYCEAE

The greens were next to the diatom in the number of species, but they played a minor role in the phytoplankton. They were mostly observed in summer, decreased abruptly in October, and again increased to the maximum number in November. The important genera were *Scenedesmus*, *Ankistrodesmus* ; but their species did never attain to abundance.

Gonium pectorale MUELLER ; PASCHER, Süssw.-fl, 4, p. 418, f. 376-379, 1927.

It appeared in several collections made in November and December. Tychoplankton. Coenobia containg 4, 8, or 16 cells.

Tetraedron minimum (A. Br.) Hansg.; Brunnthaler, in Pascher, Süssw.-fl. 5, p. 147, f. 155, 1913.

It was observed in several collections made in June and July. Cells 10–14μ in length, 4–5μ in thickness. It was once reported from Lake Harutori, Hokkaido.

Tetraedron trigonum (Naeg.) Hansg.; Brunnth. l. c. p. 149, f. 163.

It was observed in several collections made in September and October, but in small quantity.

Lagerheimia subsalsa Lemm., Forschungsber. Biol. Stat. zu Pl. 6, p. 195, pl. 6, f. 2-6, 1898. Syn. *Chodatella subsalsa* Lemm.; Brunnth., l. c. p. 139, f. 140.

It appeared in samples collected in November. Cells ovoid, with 2–4 delicate setae at each pole. Euplankton. Brackish water species.

Ankistrodesmus falcatus (Corda) Ralfs; Brunnth., l. c. p. 188, f. 283.

It was occasionally observed in samples collected in several months. Facultative plankton. Widely distributed throughout our country.

Ankistrodesmus falcatus var. *mirabilis* (W. et G. S. West) G. S. West; Brunnth., l. c. p. 188, f. 289.

It appeared in several collections made in September and November. This variety was much longer than the typical form. Cells often up to 150μ in length.

Ankistrodesmus falcatus var. *acicularis* (A. Br.) G. S. West; Brunnth., l. c. p. 188, f. 284.

This variety was observed in a single sample collected in September.

Ankistrodesmus setigerus (Schroed.) G. S. West; Brunnth., l. c. p. 191, f. 304.

It appeared in two samples collected in September and December, but in small quantity. Euplankton.

Ankistrodesmus spiralis (Turn.) Lemm.; Brunnth., l. c. p. 190, f. 293.

It appeared only in one colleetion made in November. Tychoplankton.

Dictyosphaerium Ehrenbergianum Naeg.; Brunnth, l. c. p. 183, f. 276.

It was observed in two samples in June, but it was constantly observed in nearly all collections made in November. Facultative plankton.

Pediastrum duplex Meyen; Brunnth., l. c. p. 95, f. 57.

It was observed almost constantly in nearly all collections made in November, but in small quantity. Facultative plankton.

Scenedesmus bijugatus (Turp.) Lagerh.; Brunnth., l. c. p. 167, f. 23.

It first appeared in April, and continuously increased until August, later abruptly

disappeared in September. It appeared again in November, and persisted until December. Its variety *alternans* (REINSCH) HANSG. was observed only in samples collected in November.

Scenedesmus quadricauda (TURP) BRÉB.; BRUNNTH., l. c. p. 165, f. 223.

It was observed in collections nearly the whole period except winter. It was the most important species of the genus but never attained to abundance.

Coelastrum microporum NAEG.; BRUNNTH., l. c. p. 195, f. 307.

It appeared first in April and continued until August, but in small quantity. It reappeared in November, occurring somewhat frequently. Coenobia composed of 8–32 cells.

Aphanochaete hyalothecae (HANSG) SCHMIDLE; HEERING, in PASCHER, Süssw.-fl. 6, p. 129, f. 184, 1914.

It was observed only in one sample collected in February, growing on the filaments of *Hyalotheca dissiliens*. It is very poorly known in our country.

ZYGOPHYCEAE

The so-called "desmids plankton" was not observed. Nine species of desmids formed only a very unimportant group of the phytoplankton of this lake. The relatively constant but rare occurrence of *Staurastrum tetracerum* was quite characteristic. The largest part of the *Zygophyceae* was contributed by *Spirogyra* spp. during the winter, but they disappeared entirely in summer and autumn.

Cosmarium pygmaeum ARCH.; WEST, W. & G. S., Monogr. Brit. Desm. III, p. 73, pl. 71, f. 22-31, 1908.

It appeared in several collections made in summer. Facultative plankton.

Cosmarium tenue ARCH.; WESTS, l. c. II, p. 167, pl. 61, f. 12-15, 1905.

It appeared in several samples collected in July, August, and September. The occurrence was always in small quantity.

Staurastrum tetracerum RALFS; ROY & BISS., Journ. Bot. p. 239, 1886; WESTS, l. c. V, p. 118, pl. 129, f. 2, 3, 1923; HIRANO, Acta Phytotax. et Geobot. 12, p. 163, f. 16, 1943.

It appeared in several samples collected in February, March and April. In samples collected in June, July and November, it was observed almost constantly. The plant in this lake was always the biradiate form. Body length 10–13μ; length including processes, 26–32μ; breadth including processes, 28–34μ; isthmus, 4.5–6μ.

Its variety *validum* W. et G. S. WEST was observed only in one sample collected in November.

Hyalotheca dissiliens (Smith) Breb.; Wests, l. c. V. p. 229, pl. 161, f. 16–27, 1923.

It was occasionally observed in samples collected in February, March and April. It was also found very rarely in one sample collected in January. The species was always accompanied with *Spirogyra* spp.

Mougeotia virdis (Kuetz.) Wittr.; Smith, Wisconsin Phytopl. p. 184, pl. 51, f. 1. 1920.

The alga appeared in several samples collected in February and March. It was also observed in one collection made in August (1951) and January (1952) respectively.

Spirogyra communis Kuetz.

It appeared rather abundantly in collections made in February, March and April. Rare occurrence was observed in December (1951) and January (1952). The species was almost always accompanied with several species of Diatoms. Zygote formation was observed rarely in March.

V. Summary.

Lake Mikata, a shallow basin, filled with turbid water, is communicated on the north with the brackish waters of the two lakes of Suigetsu and Suga. The phytoplankton, with reference to some limnological conditions, were in the main qualitatively analysed during the period from February in 1951 to January in 1952. Samplings were made monthly, with a single exception of May, at ten stations shown in Figure 1.

The temperature ranging between a little below 5°C and a little over 30°C and the hydrogen-ion concentration ranging between pH 7.0 and 9.7, were measured monthly at each station. The results were given in Table I and III. Thermal stratification was never marked at any time during the survey. Generally in the same investigation the temperatures and pH-values showed no considerable difference at stations in the whole area. The uniformity of these conditions was probably due to the shallowness and the intermittent mixing of the water.

Oxygen content increased in winter aud decreased in summer, showing the eutrophic nature of the lake.

Chlorine content showed as a whole the fresh-water character of the lake, except for the neighbourhood of the Seto Channel, where was found some brackish inclinatien. However, Cl content seemed to be somewhat small in winter and large in summer. From meagre results of several investigators, it might be expected that some stratification in Cl content were to be seen.

The lake had a muddy bottom and growth of higher aquatic vegetation including *Traba natans* L., *Phragmites communis* Trin., etc.

The lake had a rich plankton flora including about 170 or more species belonging to eight phyla of algae. They were in order of the number of species the

Bacillariophyceae (82), *Chlorophyceae* (35), *Cyanophyceae* (34), *Zygophyceae* (15), *Euglenophyceae* (5), *Xanthophyceae* (2), *Dinophyceae* (2), *Chrysophyceae* (1). The most important role as phytoplankton was played by the *Cyanophyceae*, followed by the *Bacillariophyceae* and then *Chlorophyceae* and *Zygophyceae*. Of 173 species identified, the greater part of the species were of fresh-water origin, and 26 species were brackish water forms. Three species were tropical elements. The monthly change of occurrence was tabulated in Table V and VI.

The most abundant occurrence of the phytoplankton was observed during the summer. The *Cyanophyceae* particularly predominated in quantity, especially in August. The predominant types were *Microcystis aeruginosa*, *Anabaena Scheremetievi* v. *recta* f. *ovalispora*; they were responsible for the water-blooms. During the winter the dominant occurrence of *Spirogyra* and several Diatoms was remarkable.

The characteristic species were considered from their abundance and constancy. Some abundant species occurred constantly throughout the year, but, of course, varying in quantity. Several species were observed constantly through the year but in small quantity. Some temporary constants were observed in large or small quantity. The characteristic species occurred usually in association with a certain species belonging to the same genus or widely different phyla of algae.

A brief notes on some characteristic species was given in Section IV. Most of the species found were cosmopolitan, and only a few endemic. A new form of *Raphidiopsis mediterranea* was described which occurred constantly in August.

VI. Literature Cited.

Brunnthaler, J. Protococcales in Pascher's Süsswasserflora Deutschland, Oesterreichs und der Schweiz. Heft 5, Chlorophyceae 2. 1915.

Geitler, L. Cyanophyceae in Rabenhorst's Kryptogamenflora von Deutschland, Oesterreich, und der Schweiz. 14, 1930–1932.

Huber-Pestalozzi, G. Das Phytoplankton des Süsswassers 1. Teil. in Thienemann's Die Binnengewässer, Band XVI, 1938.

Hustedt, F. Bacillariophyta in Pascher's Süsswasserflora. Heft 10, 1930.

Kawana, T. On the abnormal phenomenon of the Mikata Lake Group. I–III. (In Japanese) *Journ. of Fisheries* Vol. 31, Nos. 7, 8, 9, 1936.

Kokubo, S. Plankton and limnological conditions of the Mikata Lake Group in Fukui Prefecture. (In Japanese) *Ecological Review* Vol. 10, No. 4, 1947.

Okuno, H. Notes on Diatoms of Japan. I, II. *Journ. of Sci. Hirosima Univ.*, Ser. B. Div. 2, Vol. 4, Art. 5, 1940 and Vol. 5, Art. 1, 1942.

Smith, G. M. Phytoplankton of the inland lakes of Wisconsin. *Bull. Wisconsin Geol. and Nat. Hist. Survey* No. 57, 1920.

Skvortzow, B. W. Diatoms from Kizaki Lake, Honshu Isl., Nippon. *Philip. Journ. Sci.* Vol. 61, No. 1, 1936.

Skvortzow, B. W. Neogene Diatoms from Wamura, Nagano Prefecture, Central Nippon. *Mem. Col. Sci., Kyoto Imp. Univ.*, Ser. B, Vol. 12, No. 2, Art. 6, 1937.

West, W. and G. S. West. A Monograph of the British Desmidiaceae. I, 1904; II, 1905; III, 1908; V, 1923.

Yoneda. Y. Cyanophyceae of Japan. I. *Acta Phytotaxonomica et Geobotanica* Vol. 6. No. 3. 1937.

Marine Cyanophyceae from Wakasa Bay (1)

By

Isamu UMEZAKI*

With 5 Plates

Wakasa Bay is in the middle part of the Japan Sea ccast, and it is formed of eight small bays of Miyazu, Kunda, Maizuru, Uchiura, Takahama, Obama, Yashiro and Tsuruga. Our department lies at the seaside of Maizuru Bay. Wakasa Bay is blessed with abundant marine algae, so that it is an interesting coast for phycologists. However, up to the present day, no one has visited the coast for studying the marine algae except a few persons. Especially here is an unstudied bay on the Cyanophyceae. Therefore since 1948, the writer has been studying systematically marine Cyanophyceae in Wakasa Bay. Till now, the following 27 species in all were identified, namly, 4 of the Chroococcaceae, 3 of the Pleurocapsaceae, 4 of the Dermocarpaceae, 8 of the Rivulariaceae, and 8 of the Oscillatoriaceae. But more many species will be determined incontinuous studies in future.

Before going further, the writer wishes to express his best thanks to Dr. Y. YONEDA of the Department of Fisheries, Faculty of Agriculture, Kyoto University, for his kind direction during the course of the present study.

Cyanophyceae

Chroococcaceae

1. **Chroococcus turgidus** (KUETZING) NAEGELI; SETCHELL and GARDNER, in Univ. Calif. Publ. Bot. **8**(1): 10 (1919); NEWTON, Handb. Brit. Seaw. 3, fig. 1 (1931); GEITLER, Cyan. in RABENH., Kryptogamenfl. **14**: 228, figs. 109 b, 110 (1930); FREMY, Cyan. Côtes d'Eur. 24, pl.4, fig. 5 (1934); HIROSE, in Journ. Jap. Bot. **13**: 497, fig. 9 (1937); YONEDA, in Acta Phytotax. et Geobot. **6**: 187, fig. 14 a,b (1937).

Cells spherical or ellipsoidal when young, or angular from mutual compression in colonies, 1–4 in colonies, 8.5–24.5μ in diameter without teguments, 12.5–31μ in diameter with teguments. Teguments hyaline, thick, up to 4μ or rarely 6μ in thickness, often somewhat lamellate. Cell walls thin, not distinct. Protoplast light or bright blue-green, homogeneous or sometimes with dense granules. — Pl. I, fig .1.

Hab. : Ao-shima, Obama Bay (October 22, 1949). Growing among the filaments of *Calothrix pilosa* HARVEY, in the high tide level

* Botanical Laboratory

In the present material the eight or more-celled individuals could not be found, and most of them were two or four-celled. *Chroococcus turgidus* is not marine in habitat, but mostly fresh-water. Although f. *submarinus* HANSG. is described as a properly marine form, the present specimen seems to belong rather to *Chr. turgidus*.

2. Aphanocapsa marina HANSGIRG; GEITLER, l. c. 154, fig. 66 c (1930); FREMY, l. c. 16, pl. 3, fig. 2 (1934); in Dansk. Bot. Arkiv. **9**: 5 (1939); UMEZAKI, in Journ. Jap. Bot. **27**:219, fig. 20 A (1952).

Colonies mostly small spherical, mucous, dirty blue-green. Cells densely aggregated within a hyaline mucous stratum, spherical, 0.4–0.5μ in diameter, single or two in pair, surrounded by a very thin hyaline membrane. Protoplast light yellow, homogeneous.—Pl. I, fig. 2.

Hab.: Kane-ga-saki, Maizuru Bay (July 10, 1950). Growing among the strata of other Cyanophyceae.

A little specimens were found from a single locality mentioned above.

3. Aphanocapsa littoralis HANSGIRG; GEITLER, l. c. 153, fig. 66 b (1930); FREMY, l. c. 15, pl. 3, fig. 1 (1934); UMEZAKI, l. c. **27**: 219, fig. 20 B (1952).

Colonies mucous, spherical or irregular form. Cells spherical, divided by one plane, yellowish green, 4–6μ in diameter, loosely or densely arranged within a colony. —Pl. I, fig. 3.

Hab.: Kato, Obama Bay (June 21, 1949). Growing among the fronds of *Lyngbya majuscula* HARVEY; Koiso, Maizuru Bay (May 23, 1952). Among small other algae or Cyanophyceae.

This species was sometimes found among the fronds of Cyanophyceae or other small algae. The characteristics are typical.

4. Merismopedia glauca (EHRENB.) NAEGELI; GEITLER, Cyan. in PASCHER, Süsswasserfl. **12**: 106, fig. 125 (1925); l. c. 264, fig. 129 d (1930); FREMY, l. c. 7, pl. 1, fig. 2 (1934); HIROSE, l. c. **13**: 570, fig. 17 (1937); YONEDA, l. c. **6**: 191, fig. 21 (1937); NEWTON, l. c. 8, fig. 7 (1931).

Colonies floating or among other algae, light blue-green, composed of 8–64 cells, mostly 8–32. Cells spherical or oval, 3–5 (-5.5)μ in diameter. Protoplast light blue-green, homogeneous.—Pl. I, fig. 4.

Hab.: Koiso, Maizuru Bay (August 18, 1950; May 23, 1952). Floating or among the fronds of *Phormidium* or *Cladophora*, in a tide pool, a litrle above the high tide level.

This species is rare.

Pleurocapsaceae

5. Xenococcus acervatus SETCHELL et GARDNER; GARDNER, in Univ. Calif. Publ. Bot. **6**: 459, pl. 39, fig. 13 (1918); SETCHELL and GARDNER, l. c. 31, pl. 5, fig. 13 (1919); GEITLER, l. c. 333, fig. 168 (1931); FREMY, l. c. 43, pl. 8, fig. 6 (1934).

Cells epiphytic, forming one cell deep colonies or more or less heaped up, spherical, pear-shaped or angular, divided into four cells by two planes, 2.5–6μ in diameter, mostly 3–5μ. Cell walls thin, hyaline. Endospores unknown.—Pl. I, fig. 5.

Hab.: Tagarasu, Yashiro Bay (December 23, 1949). Epiphytic on *Lyngbya* sp. growing in the littoral zone.

The present species is rare in Wakasa Bay, but it was very abundantly found epiphytic on the filaments of *Lyngbya* sp., from a single locality, viz. Tagarasu of Yashiro Bay. This species is a new record for Japan.

6. Xenococcus Schousboei THURET; BORNET and THURET, Notes Algol. **2**: 74–76, pl. 26, figs. 1,2 (1880); NEWTON, l. c. 9 (1931); GEITLER, l. c. 335, fig. 170 (1931); FREMY, l. c. 43, pl. 8, fig. 5 (1934); UMEZAKI, l. c. **25**: 225, fig. 2 (1950).

Cells wholly epiphytic on other algae, blue-green or yellowish green, single or closely gregarious, spherical or angular under mutual compression, 4–9μ in diameter. Membranes thin, hyaline, not lamellate. Cell contents homogeneous.

Hab.: Wakasa-takahama, Takahama Bay (November 22, 1949). Epiphytic on *Lyngbya majuscula* HARVEY growing on *Grateloupia divaricata* OKAMURA; Jya-jima, Maizuru Bay (October 8, 1951). On *Lyngbya* sp.

This species is at times observed.

7. Xenococcus pyriformis SETCHELL et GARDNER; GARDNER, l. c. 463, pl. 39, fig. 12 (1918); SETCHELL and GARNDER, l. c. 34, pl. 5, fig. 12 (1919); GEITLER, l. c. 336, fig. 172 (1931); UMEZAKI, l. c. **25**: 224, fig. 1 (1950).

Cells epiphytic on other algae, single or forming small confluent colonies, angular, pear-shaped, or hemispherical, 9–18.5μ in diameter, 12–24.5μ in length. Protoplast yellowish green or light green. Cell walls conspicuous, thick, hyaline. Endosporangium with numerous endospores of 2.8–3.5μ in diameter, formed by successive divisions of the protoplast.—Pl. I, fig. 7.

Hab.: Nagahama, Maizuru Bay (February 20, 1952). Epiphytic on *Chaetomorpha* sp. growing on rocks, in the high tide level.

The writer collected this species epiphytic on *Cladophora* sp. from the Muroran coast of Hokkaido in 1947, and it was published in his paper "Marine Cyanophyceae from Japan (1)" as a new record from Japan. The present specimens were abundantly found on *Chaetomorpha* sp. from Nagahama in Maizuru Bay.

Dermocarpaceae

8. Dermocarpella hemisphaerica LEMMERMANN; GEITLER, l. c. 386, fig. 213 (1931).

Cells epiphytic on other algae, usually solitary, hemispherical, 19–28μ in diameter, 12–21.5μ in height. Membranes hyaline, lamellate, 1.5–5.5μ in thickness. Endopores not found.—Pl. I, fig. 8.

Hab.: Nagahama, Maizuru Bay(September 12, 1949). Epiphytic on *Gelidium*

Amansii LMX.; Jya-jima, Maizuru Bay (October 8, 1951). On *Lyngbya* sp.

The cells having endospores could not be found, but some cells were sometimes dividing into two or three protoplasts by one or two planes parallel to host. This species is new to Japan.

9. Dermocarpa sphaerica SETCHELL et GARDNER; GARDNER, l. c. **6**: 457, pl. 39, fig. 14 (1918); SETCHELL and GARDNER, l. c. **8**: 24, pl. 5, fig. 14 (1919); GEITLER, l. c. 393, fig. 217 (1931); FREMY, l. c. 58, pl. 16, fig. 2 (1934); *Xenococcus Gilkeyae* SETCHELL et GARDNER in UMEZAKI, l. c. **27**: 220, fig. 20 (1952).

Cells epiphytic, solitary or forming a small colony, pale blue-green, 8 (4) -16μ in diameter, spherical. Cell membranes thin, but sometimes thick, hyaline. Protoplast finely granular. Endosporangium with numerous and spherical endospores of 2.5–3μ in diameter, formed by simultaneous or rarely successive divisions of the protoplast. —Pl. I, fig. 6.

Hab.: Sanbon-matsuhana, Maizuru Bay (Sept. 25, 1949). Epiphytic on *Lyngbya* sp.; Wakasa-takahama, Takahama Bay (January 15, 1950). On *Calothrix pilosa* HARVEY; Jya-jima, Maizuru Bay (August 23, 1951). On *Lyngbya semiplena* AGARDH.

The materials published as *Xenococcus Gilkeyae* SETCHELL et GARDNER in the writer's previous paper, Marine Cyanophyceae from Japan (5), seem to be placed under *Dermocarpa sphaerica* SETCHELL et GARDNER, although the endospore formation is partly resemblance to that of *Xenococcus Gilkeyae*. This species is fairly common and it is a new addition to the marine Cyanophyceae flora of Japan.

10. Dermocarpa Leibleiniae (REINSCH) BORNET et THURET, Notes Algol. **2**: 73, pl. 25, figs. 3–5 (1880); NEWTON, l. c. 9 (1931); GEITLER, l. c. 399, fig. 224 (1931); FREMY, l. c. 61, pl. 17, fig. 3 (1934); UMEZAKI, l. c. **25**: 225, fig. 3 (1950).

Cells growing on other algae, mostly solitary, spherical when young, later becoming oblong or ellipsoidal, bright blue-green, 9–18.5μ in diameter, 9–30μ in length. Cell membranes thick, 1.2–2μ in thickness, lamellate, hyaline. Endosporangium with 4–15 endospors formed by successive divisions of the protoplast in the upper part. Endospores spherical or angular, 3.5–8.5μ in diameter within the sporangium.

Hab.: Wakasa-takahama, Takahama Bay (November 22, 1949). Growing on *Sphacelaria* sp.

This species is rare and the present specimen was published by the writer in 1950.

11. Dermocarpa protea SETCHELL et GARDNER; GARDNER, l. c. 456, pl. 38, figs. 4, 5 (1918); SETCHELL and GARDNER, l. c. 28, pl. 4, figs. 4, 5 (1919); GEITLER, l. c. 398, fig. 222 (1931); YAMADA and TANAKA, in Mon. Rep. Hokkaido Fish. Exp. Stat. **1**: 116 (1934); TOKIDA, in Trans. Sapporo Nat. Hist. Soc. **15**: 212 (1938).

Cells epiphytic on other algae, forming minute blackish green colonies, very variable in shape and size, ellipsoidal, broad pear-shaped or cunei-form, 12–39μ in diameter at the apical broad portions, slender at the basal portions, 22–60μ in length.

Cell walls hyaline, homogeneous or sometimes lamellate, 2–3μ in thickness. Protoplast homogeneous, light or deep blue-green. Endospores formed by successive divisions of the protoplast, spherical, numerous, 2.5–3.5μ in diameter within a sporangium—Pl. I, fig. 9.

Japanese name: Kikka-awoko (J. TOKIDA).

Hab.: Kanmuri-shima, off Maizuru Bay (May 18, 1952). Epiphytic on *Lomentaria* sp. and *Corallina pilulifera* P. et R. f. *filiformis* RUPR.

In Japan, *Dermocarpa protea* SETCH. et GARDN. was collected from Utoro, Shiretoko Peninsula, Hokkaido by Y. YAMADA and T. TANAKA in 1934, and J. TOKIDA has published a detailed observation on this species epiphytic on *Myelophycus caespitosus* (HARV.) KJELLM., from Shirahama, Prov. Bōsyū, and Cape Inuboe. In TOKIDA's specimen the mature cells are described to be 45–126μ long and 18–34μ wide at the apices, and that the endospores are formed by successive and progressive divisions of the whole protoplast of the sporangium. The writer could see the specimen collected from Utoro by Y. YAMADA and T. TANAKA, when he underwent his graduation examination under the direction of Prof. Y. YAMADA in 1947, in the Botanical Institute, Faculty of science, Hokkaido University. The present material from Kanmuri-shima is very similer to the specimen of Y. YAMADA and T. TANAKA.

Rivulariaceae

12. Calothrix parasitica (CHAUV.) THURET; BORNET and THURET, Notes Algol. 2: 157, pl. 37, figs. 7-10 (1880); BORNET and FLAHAULT, Rev. 1: 357 (1886); SETCHELL and GARDNER, l. c. 98 (1919); NEWTON, l. c. 33 (1931); GEITLER, l.c. 597, fig. 374 a, b (1931); FREMY, l. c. 139, pl. 33. figs. 1-4 (1934).

Filaments endophytic among the cortical threads of Nemalion, solitary or mostly aggregated, blue-green, short or long, up to 500μ in length, the base thickened or somewhat bulbous, sometimes curved, 10.5–15.5μ in diameter, the middle 6–8.5μ in diameter. Sheaths hyaline, thickened at the base and then narrow gradually from the middle upwards, but often dilate at the apex and lamellate. Trichomes blue-green, 7–12μ in diameter at the base, 4.6–6μ in diameter at the middle, and then tapering into very long flexuous hyaline hairs above. Cross walls not or constricted. Heterocysts basal, usually single, hemispherical. Hormogonia from two to several within a sheath, 15–35μ in length, 3–6 times longer than the diameter. —Pl. II, fig. 1.

Hab.: Kato, Obama Bay (June 22, 1949). Endophytic in the fronds of *Nemalion helminthoides* (VELLEY) BATTERS.

This species is surely found endophytic in the old fronds of *Nemalion helminthoides* (VELLEY) BATTERS and their host plants are usually discoloured into deep blue-green by the parasitism of *Calothrix parasitica*. For the purpose of parasitism of this alga *Nemalion* plant seems to be more favorable host than other mucous algae.

13. Calothrix scopulorum (W. et M.) AGARDH, Syst. Alg. 70 (1824); BORNET and THURET, Notes Algol. 2: 159, pl. 38 (1880); SETCHELL and GARDNER, l. c. 96(1919); NEWTON, l. c. 33(1931); GEITLER, l. c. 600, fig. 374 f, g(1931); FREMY, l. c. 143, pl. 35, fig. 2 (1934).

Filaments densely and widely expanded on rocks, straight, but somewhat curved at the basal portion, 300–1050μ in height, 12–17μ in diameter at the base, 12–15μ in diameter at the middle. Sheaths hyaline, up to 3μ in thickness, repeatedly lamellate. Trichomes yellowish green to light blue-green, tapering into a long hyaline hair above, 8.5–12μ in diameter at the base, 7.5–12μ in diameter at the middle. Cross walls constricted at the basal part, but generally not constricted from the middle upwards. Cells 2–6.5μ in length, from nearly quadrate to 1/3 time as long as the diameter. Hormogonia 2–4 within a sheath, 30–62μ in length, 3.5–7 times as long as the diameter. Heterocysts basal, single or several, quadrate or depressed.—Pl. II, fig. 2.

Hab.: Koiso, Maizuru Bay (September 25, 1949; November 11, 1949). Growing on rocks near the high tide level; Tagarasu, Yashiro Bay(December 23, 1949). Growing on rocks in the high tide level.

Calothrix scopulorum is listed in "Synopt. List Jap. Alg.(1916)" written by K. OKAMURA in anticipation of its distribution in the Japanese coast, by reason of widely distributed species in the world. This species was abundantly found in Maizuru Bay and Yashiro Bay.

14. Calothrix nodulosa SETCHELL et GARDNER, in Proc. Calif. Acad. Sci. 4 Ser. 12: 702, pl. 12, figs. 9, 10 (1924); GEITLER, l. c. 1174 (1932).

Filaments epiphytic on other algae, decumbent at the basal portion and erect above, not branching, blue-green to grass green, 300–900μ in length, somewhat thick at the base, 21–31.5μ in diameter at the base, 18.5–24.5μ in diameter at the middle. Sheaths hyaline to yellowish, 2–4.5μ in thickness, lamellate, open at the apex. Trichomes grass green to blue-green, 17–20μ in diameter at the base, 13–17μ in diameter at the middle, tapering rather abruptly into hyaline short hairs above. Cell contents often with dense granules. Cells 1/2–1/5 time as long as the diameter, more shorter at the upper portion. Heterocysts basal, sinlge when young, two or rarely up to five when old, cream yellow, cylindrical, quadrate, hemispherical or crescent. Hormogonia 1–10 or 15 within the sheath, 24.5–43μ in length, 2–3.5 times as long as the diameter.—Pl. III, fig. 2.

Hab.: Kato, Obama Bay(June 22, 1949). Epiphytic on *Laurencia* sp.

In the fact that numerous hormogonia are formed on the filaments, the present specimen seems to be rather more well matured plant than the original type published by SETCHELL and GARDNER. This species is new to Japan.

15. Calothrix crustacea THURET; BORNET and THURET, Notes Algol. 1: 13—16, pl. 4(1878); SETCHELL and GARDNER, l. c. 99(1919); NEWTON, l. c. 34, fig. 23(1931); GEITLER, l. c. 601, fig. 375 b(1931); FREMY, l. c. 146, pl. 38, fig. 2(1934).

Fronds blue-green or olive green, widely expanded on rocks. Filaments attached by the base or sometimes at the middle, erect or somewhat flexuous, sometimes falsely branched, somewhat thick at the base, 21–27.5μ in diameter, 800–1300μ in height. Sheaths hyaline or cream yellow, 3–6μ in thickness, repeatedly lamellate. Trichomes light blue-green or yellowish green, 14–18.5μ in diameter at the middle, tapering into very long hyaline hairs above. Cross walls slightly constricted. Cells 1/2–1/6 time as long as the diameter. Heterocysts basal and intercalary; basal ones single, hemispherical; intercalary ones several, short, quadrate or cylindrical. Hormogonia numerous within a sheath, 25–50μ in length, 1.5–3 times longer than the diameter. – Pl. II, fig. 3 & Pl. III, fig. 1.

Hab.: Kato, Obama Bay (September 8, 1949). Growing on rocks in the high tide level; Wakasa-takahama, Takahama Bay (September 26, 1949). On rocks in a tide pool, in the high tide level.

This species is often found.

16. Calothrix pilosa HARVEY, in Ner. Bor. Amer. **3**: 106, pl. 48c (1858); BORNET and FLAHAULT, Rev. **1**: 363 (1886); SETCHELL and GARDNER, l. c. 102, pl. 8, fig. 4 (1919); GEITLER, l. c. 611 (1931); FREMY, in Dansk. Bot. Arkiv. **9**: 36, fig. 4 (1939).

Filaments forming a widely and densely expanded, caespitose, pilose, dark green stratum on rocks, black on drying, decumbent and then both ends erect upwards, elongate, rigid, sometimes with Scytonema-like branching, up to 5 mm. in height, 30–39μ in diameter. Sheaths firm, hyaline or mostly light brown at the decumbent portions, mostly lamellate, 4.5–9μ in thickness. Trichomes 15–24 5μ in diameter, olive brown or light blue-green, rather briefly attenuate into short hyaline hairs or buttom-like above. Cross walls not constricted or sometimes slightly constricted. Cells 3–9μ in length, 1/2–1/8 time as long as the diameter, generally short at the upper portions of trichomes, long at the decumbent portions. Heterocysts intercalary, several, depressed, quadrate or cylindrical. Hormogonia unknown.—Pl. III fig. 3.

Hab.: Wakasa-takahama, Takahama Bay (September 26, 1949). Growing on rocks a little above the high tide level; Ao shima, Obama Bay (June 25, 1949; October 22, 1949). Growing on rocks; Obama, Obama Bay (December 10, 1949). Growing on rocks.

This alga is one of the most common species among Cyanophyceae found in Wakasa Bay. It is fairly and readily recognized in forming a widely expanded and velvety stratum on rock in the uppermost high tide level. And it is a species having the longest filament in the genus *Calothrix* from Wakasa Bay.

17. Isactis plana (HARVEY) THURET; BORNET and THURET, Notes Algol. **2**: 163, pl. 40 (1880); SETCHELL and GARDNER, l. c. 105 (1919); NEWTON, l. c. 35, fig. 25 (1931); GEITLER, l. c. 656, fig. 418 (1931); WOMERSLEY, in Trans. Roy. Soc. S. Aust. **70**: 128, fig. 1 A (1946).

Fronds deep blue-green, widely expanded, up to 4 cm. across, up to 400μ in height, not zonate. Filaments scarcely branched, parallelly erect. Sheaths hyaline, but above yellowish brown, lamellate. Trichomes somewhat thick at the base, 5.5–12μ in diameter at the base, 5–9.5μ in diameter at the middle, tapering into a long hyaline hair above. Cross walls conspicuously constricted. Cells 1–1/3 time as long as the diameter. Heterocysts basal, 1–3, spherical or ellipsoidal. Hormogonia unknown —Pl. IV, fig. 1.

Hab.: Toshima, Maizuru Bay (August 13, 1949); Kato, Obama Bay (September 8, 1949); Koiso, Maizuru Bay (September 25, 1949); Wakasa-takahama, Takahama Bay (September 26, 1949). Growing on rocks in the high tide level.

This plant in Wakasa Bay seems to belong to var. *plana* Born. and Flah. of which the frond is not zonate. The present species is one of the most common Cyanophyceae in Wakasa Bay.

18. Rivularia atra Roth; Bornet and Flahault, Rev. **2**: 353 (1886); Setchell and Gardner, l. c. 107 (1919); Newton, l. c. 38, fig. 26 (1931); Geitler, l. c. 645, fig. 410 b, c (1931); Fremy, l. c. 153, pl. 42, fig. 2 (1934); Womersley, l. c. 132, fig. 1 B (1946).

Fronds blackish green, very hard, solitary or sometimes confluent, hemispherical, 2–4 mm. in diameter. Filaments tightly compact, abundantly falsely branched, not separating readily under pressure, blue-green or light blue-green. Sheaths hyaline or yellowish, thin, scarcely distinct. Trichomes 2–4μ in diameter below, 4–5.5μ in diameter above, and then tapering into a long hyaline hair. Lower cells 9–16μ in length, 3–6 times as long as the diameter; upper cells 2.5–3μ in length, 1–1/2 time as long as the diameter. Cross walls very sligtly or not constricted. Dissepiments generally obscure in the lower cells. Heterocysts basal, single, spherical or sometimes ellipsoidal, 5.5– 11μ in diameter.—Pl. IV, fig. 2.

Hab.: Kato, Obama Bay (September 8, 1949). Growing on rocks in the high tide level or a little above; Wakasa-takahama, Takahama Bay (September 26, 1950). On rocks in the high tide level.

This species seems to be common on the Japanese coast as listed in "Synopt. List Jap. Alg. (1916)" by K. Okamura, and it is very commonly distributing in every place of Wakasa Bay. The var. *hemisphaerica* Born. and Flah. was collected from Utoro, Shiretoko Peninsula, Hokkaido, by Y. Yamada and T. Tanaka in 1934.

19. Rivularia nitida Agardh; Bornet and Flahault, Rev. **2**: 357 (1886); Setchell and Gardner, l. c. 108 (1919); Newton, l. c. 38 (1931); Geitler, l. c. 646 (1931); Fremy, l. c. 154, pl. 43, fig. 2 (1934); Womersley, l. c. 132, fig. 1 C (1946).

Fronds hollow, deeply plicate on the surface, dark blue-green, single or united together, 1–2 cm. broad. Filaments densely crowded, not readily separable under

pressure. Sheaths light brown and open above, hyaline below. Trichomes blue-green, tapering gradually into a long hyaline hair above, 3.5–7.5μ in diameter above, 2.5–5μ in diameter below. Cross walls mostly constricted or sometimes not. Cells 2.5–9μ in length, 1/2–3 times as long as the diameter, generally short at the upper portion. Heterocysts basal, 5–15μ in diameter, spherical or hemispherical. Hormogonia single within a sheath, 21.5–29μ in length, 5–6.5 times as long as the diameter.—Pl. IV, fig. 3.

Hab.: Kato, Obama Bay (May 29, 1949). Growing on rocks in the littoral zone; Obama, Obama Bay (December 8, 1949); Wakasa-takahama, Takahama Bay (September 26, 1949); Sanbon-matsuhana, Maizuru Bay (November 8, 1949).

The present species is common and new to Japan.

Oscillatoriaceae

20. Lyngbya sordida (Zanard.) Gomont, Monogr. des Ocill. 126, pl. 2, fig. 21 (1892); Geitler, l. c. 1039, fig. 657 b (1932); Fremy, l. c. 103, pl. 26, fig. 5 (1934); Umezaki, l. c. **25**: 227, fig. 6 (1950).

Filaments dark-green, forming a tuft on other algae, attached by the middle portion, 2 cm. in height, 24.5–30.5μ in diameter. Sheaths thin, hyaline, not lamellate, firm, up to 2 (rarely 4) μ in thickness. Trichomes yellowish green, 21.5–29μ in diameter, not tapering at the ends. Cross walls conspicuously constricted. Dissepiments not granulated. Cells 3–9μ in length, 1/2–1/6 time as long as the diameter. Terminal cells rounded, without calyptra.—Pl. V, fig. 1.

Hab.: Kato, Obama Bay (September 9, 1949). Growing on *Corallina* sp.; Nagahama, Maizuru Bay (September 12, 1949). Growing on *Gelidium Amansii* Lmx; Ao-shima, Obama Bay (October 22, 1949). Growing on *Sargassum piluliferum* C. Ag.

21. Lyngbya majuscula Harvey; Gomont, l. c. 131, pl. 3, figs. 3, 4 (1892); Geitler, l. c. 1060, fig. 672 c, d (1932); Fremy, l. c. 106, pl. 28, fig. 1 (1934); Newton, l. c, 23, (1931).

Fronds deep blue-green, up to 3 cm. in height. Filaments 24–30μ in diameter. Sheaths hyaline, not or lamellate, 3–5μ in thickness. Trichomes 15.5–23μ in diameter. Cross walls not constricted. Dissepiments not granulated. Cells very short, 1/5–1/15 time as long as the diameter. Apical cells rotund, without calyptra.—Pl. V, fig. 2.

Hab.: Kato, Obama Bay (June 22, 1949). Growing on rocks or *Laurencia* sp. in the high tide level; Kanmuri-shima, off Maizuru Bay (July 23, 1949). Growing on rocks in the littoral zone; Suizu, Tsuruga Bay (August 5, 1950). Growing on *Corallina* sp.

This species was found forming a dense large tuft on rocks or on other algae. The alga is readily distinguished by a cursory glance from other species of the genus *Lyngbya* collected from Wakasa Bay, by the thick trichomes which are very short cells.

22. Lyngbya lutea (AGARDH) GOMONT, in Journ. de Bot. **4** : 354 (1890); l. c. 141, pl. 3, figs. 12, 13 (1892); GEITLER, l. c. 1057, fig. 670 a, b (1932); FREMY, l. c. 109, pl. 28, fig. 4 (1934); UMEZAKI, l. c. **26** : 204, fig. 11 (1951).

Plant mass somewhat mucous, yellowish green. Filaments 4–8 (11)μ in diameter, up to 3 mm. in height. Sheaths hyaline, smooth in outline, very thin when young, later becoming more thicker and lamellate, up to 3μ in thickness. Trichomes olive-green, 2.5–5μ in diameter, not tapering at the apices. Cross walls not constricted. Dissepiments not or rarely granulated. Cells mostly 1/2-1/3 time as long as the diameter or nearly quadrate. Apical cells with rounded calyptra. —Pl. V, fig. 3.

Hab.: Nagahama, Maizuru Bay (December 1, 1949). Growing on rocks a little above the high tide level; Obama, Obama Bay (December 10, 1949). Growing on rocks, associated with other Cyanophyceae, in the high tide level; Koiso, Maizuru Bay (March 10, 1950). On rocks a little above the high tide level.

This species is common, and usually it is found associated with other Cyanophyceae.

23. Symploca muscorum (AGARDH) GOMONT, in Journ. de Bot. **4**: 354 (1890); l. c. 110, pl. 2, fig. 9 (1892); GEITLER, l. c. 1122, fig. 730 (1932); FREMY, l. c. 82, pl. 22, fig. 2 (1934).

Fronds Phormidium-like membraneous, growing on rocks or on other algae, light blue-green, up to 1 cm. broad. Filaments irregularly intricate, creeping. Sheaths hyaline, firm, not mucous, do not turn violet with chlor-zinc iodine. Trichomes blue-green, 5–6.3μ in diameter, not tapering at the ends. Cross walls not constricted. Dissepiments not granulated. Cells 4.5–9.2μ or 12μ in length, from nearly quadrate to 2 (2.5) times as long as the diameter. Endcells rounded, with somewhat thickened outer membranes. —Pl. V, fig. 4.

Hab.: Kato, Obama Bay (June 21, 1949). Growing on *Laurencia* sp.; Tagarasu, Yashiro Bay (December 23, 1949). Growing on rocks in the littoral zone.

This species is rather more generally distributed in fresh water than in marine in habitat, but it is sometimes found on the seacoast, as reported from the French coast by P. FRÉMY in 1934. As stated above, the characteristics of the present alga seem to agree well with those of fresh-water plant.

24. Microcoleus tenerrimus GOMONT, l. c. 355, pl. 14, figs. 9–11 (1892); SETCHELL and GARDNER, l. c. 87 (1919); GEITLER, l. c. 1135, fig. 740 (1932); FREMY, l. c. 68, pl. 17, fig. 8 (1934); GARDNER, in Sc. Surv. Porto Rico & Virgin Isl. **8**: 288 (1932); UMEZAKI, l. c. **27**: 119, fig. 17 (1952); NEWTON, l. c. 27 (1931).

Filaments dispersed among other algae, blue-green, flexuous, not branched. Sheaths hyaline, mostly diffluent. Trichomes pale blue-green, 1.5-2μ in diameter, mostly numerous within the sheath. Cross walls constricted. Dissepiments pellucid, not granulated. Cells 2–6μ in length, from nearly quadrate to 3 times longer than the diameter. Cell contents homogeneous. Apical cells somewhat longer and

acutely tapering, neither calyptrate nor capitate.—Pl. V, fig. 5.

Hab.: Kato, Obama Bay (September 8, 1949). Growing among the filaments of *Calothrix pilosa* HARVEY.

On'y a few filaments were found among the filaments of *Calothrix pilosa* HARVEY. Up to the present day, the writer collected this species from other places, Yoshimi, Shimonoseki City, Yamaguchi Pref. and Seto, Shirahama, Wakayama Pref.

25. Hydrocoleum cantharidosmum (MONT.) GOMONT, in Journ. de. Bot. **4**: 353 (1890); l. c. 336, pl. 12, figs. 6, 7 (1892); GEITLER, l. c. 1148, fig. 755 (1932).

Fronds olive green, mucous, 1 cm. in height. Filaments sparsely branched, erect or somewhat curved. Sheaths hyaline, thick, very mucous, here and there lamellate. Trichomes 20–23.5μ in diameter, blue-green, few within the sheath, parallel, or loosely twisted, not or slightly tapering at the apex. Cross walls not constricted. Dissepiments not or granulated. Cells 1/5–1/9 time as long as the diameter, 2.5–4μ in length. Apical cells with calyptra.—Pl. V, fig. 6.

Hab.: Koiso, Maizuru Bay (May 22, 1948). Growing on rocks in the littoral zone; Kato, Obama Bay (June 22, 1952). Growing on rocks in the littoral zone.

This species is common, and it is new to Japan.

26. Hydrocoleum lyngbyaceum KUETZING, Species Algar. 259 (1849); GOMONT, l. c. 337, pl. 12, figs. 8–10 (1892); SETCHELL and GARDNER, l. c. 85, pl. 1, fig. 10 (1919); GEITLER, l. c. 1150, fig. 757 (1932); FREMY, l. c. 72, pl. 19, fig. 1 (1934); NEWTON, l. c. 29, fig. 20 (1931); UMEZAKI, l. c. **26**: 269, fig. 16 (1951).

Fronds forming a mucous, dark green stratum. Filaments branched above. Sheaths hyaline, thick, irregular in outline, sometimes completely diffluent. Trichomes several within the sheath, twisted into loose spiral, 9–13μ in diameter, slightly tapering at the apices. Cross walls not constricted. Dissepiments mostly granulated. Cells 2 3–4μ in length, 1/3–1/6 time as long as the diameter. Terminal cells with a thickened watch glass-like calyptra.—Pl. V, fig. 7.

Hab.: Kato, Obama Bay (August 10, 1949). Growing on *Champia parvula* (Ag) J. Ag. and *Laurencia* sp.; Wakasa-takahama, Takahama Bay (September 26, 1949). Growing on rocks in a tide pool, in the high tide level; Koiso, Maizuru Bay (February 3, 1950). Growing on rocks near the high tide level.

The present species is common, and it forms a large expanded stratum on rocks or sometimes among Cyanophyceae algae.

27. Schizothrix septentrionalis GOMONT, in Bull. Soc. Bot. Franc. **46**: 27, pl. 1, figs. 1–4 (1899); GEITLER, l. c. 1110 (1932).

Filaments somewhat flexuous, branched at the upper part. Sheaths yellowish brown, firm, lamellate. Trichomes light blue-green, 1–3 within the sheath, 1.5–2.3μ in diameter. Cross walls conspicuously constricted. Dissepiments not granulated. Cells 1/2–1/3 time as long as the diameter. Terminal cells rounded.—

Pl. V, fig. 8.

Hab.: Kanmuri-shima, off Maizuru Bay (July 23, 1949). Growing on rocks in the littoral zone.

In this specimen the branching is sparse, but it seems to belong to *S. septentrionalis*. This alga is rare, and new to Japan.

EXPLANATION OF PLATES

PLATE I

1. *Chroococcus turgidus* (KUETZING) NAEGELI: Colonies of one–, two–, and four-celled stages, ×450.
2. *Aphanocapsa marina* HANSGIRG: A colony, ×900.
3. *Aphanocapsa littoralis* HANSGIRG: A colony, ×400.
4. *Merismopedia glauca* (EHRENB.) NAEGELI: A 32-celled colony, ×650.
5. *Xenococcus acervatus* SETCHELL et GARDNER: A group of epiphytic cells on *Lyngbya*, of which some are divided into two or four cells, ×900.
6. *Dermocarpa sphaerica* SETCHELL et GARDNER: A group of vegetative cells and sporangia in various stages of development, ×750.
7. *Xenococcus pyriformis* SETCHELL et GARDNER: Various vegetative cells and sporangia in various stages of endospore formation, ×400.
8. *Dermocarpella hemisphaerica* LEMMERMANN: Two vegetative cells and sporangia divided into two and three endospores, ×400.
9. *Dermocarpa rotea* SETCHELL et GARDNER: Vegetative cells, two matured sporangia and one sporangium in developmental process of endospore formation, ×400.

PLATE II

1. *Calothrix parasitica* (CHAUV.) THURET: a. A filament ending into a long hyaline hair, ×400; b. A filament having four hormogonia at the apex, ×400.
2. *Calothrix scopulorum* (W. et M.) AGARDH: Two filaments, of which one is up to the middle portion, ×400.
3. *Calothrix crustacea* THURET: A filament, ×150.

PLATE III

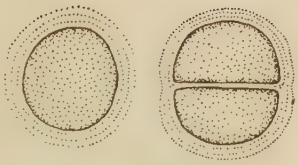
1. *Calothrix crustacea* THURET: Habit of the filaments, ×30.
2. *Calothrix noduolsa* SETCHELL et GARDNER: Young and matured filaments with hormogonia, ×250.
3. *Calothrix pilosa* HARVEY: a. Habit sketch of the filaments, ×15; b. End portions of filaments ending in a short hair and buttom-like; c. Middle portion of a filament; d. A filament showing Scytonema-branching. b, c, d. ×150.

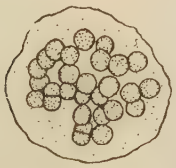
PLATE IV.

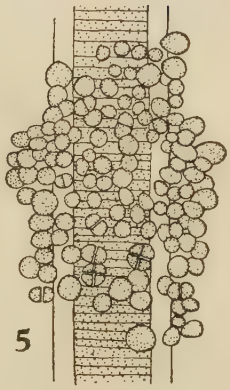
1. *Isactis plana* (HARVEY) THURET: a. A part of vertical section of frond, ×120; b. Magnification of a part of a, ×450.
2. *Rivularia atra* ROTH: c. A part of vertical section of frond shows the radiating filaments and concentric zones of heterocysts, ×20; d. Magnification of a part in upper portion of c, ×650.
3. *Rivularia nitida* AGARDH: e. A part of vertical section of frond, ×30; f. Magnification of a part of e, ×300.

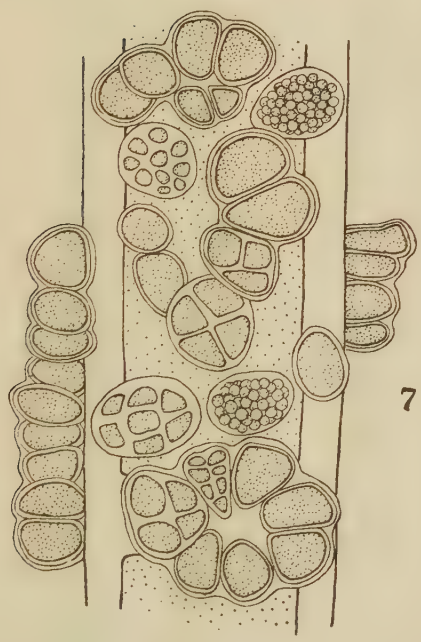
PLATE V

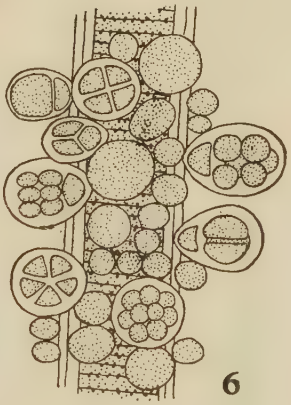
1. *Lyngbya sordida* (ZANARD.) GOMONT: End portion of a filament, ×400.
2. *Lyngbya majuscula* HARVEY: End portion of a filament, ×400.
3. *Lyngbya lutea* (AGARDH) GOMONT: a. A young filament, ×1000; b. A well matured filament, ×1000.
4. *Symploca muscorum* (AGARDH) GOMONT: End portions of two filaments, ×400.
5. *Microcoleus tenerrimus* GOMOMT: End portions of two trichomes, ×1000.
6. *Hydrocoleum cantharidosmum* (MONT.) GOMONT: a. Habit of a filament, ×65; b. End protion of a filament with one trichome, × 400.
7. *Hydrocoleum lyngbyaceum* KUETZING: End portion of a filament, ×450.
8. *Schizothrix septentrionalis* GOMONT: a. Habit of a filament, ×400; b. End portion of a filament, ×1000.











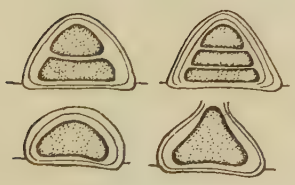


PLATE I

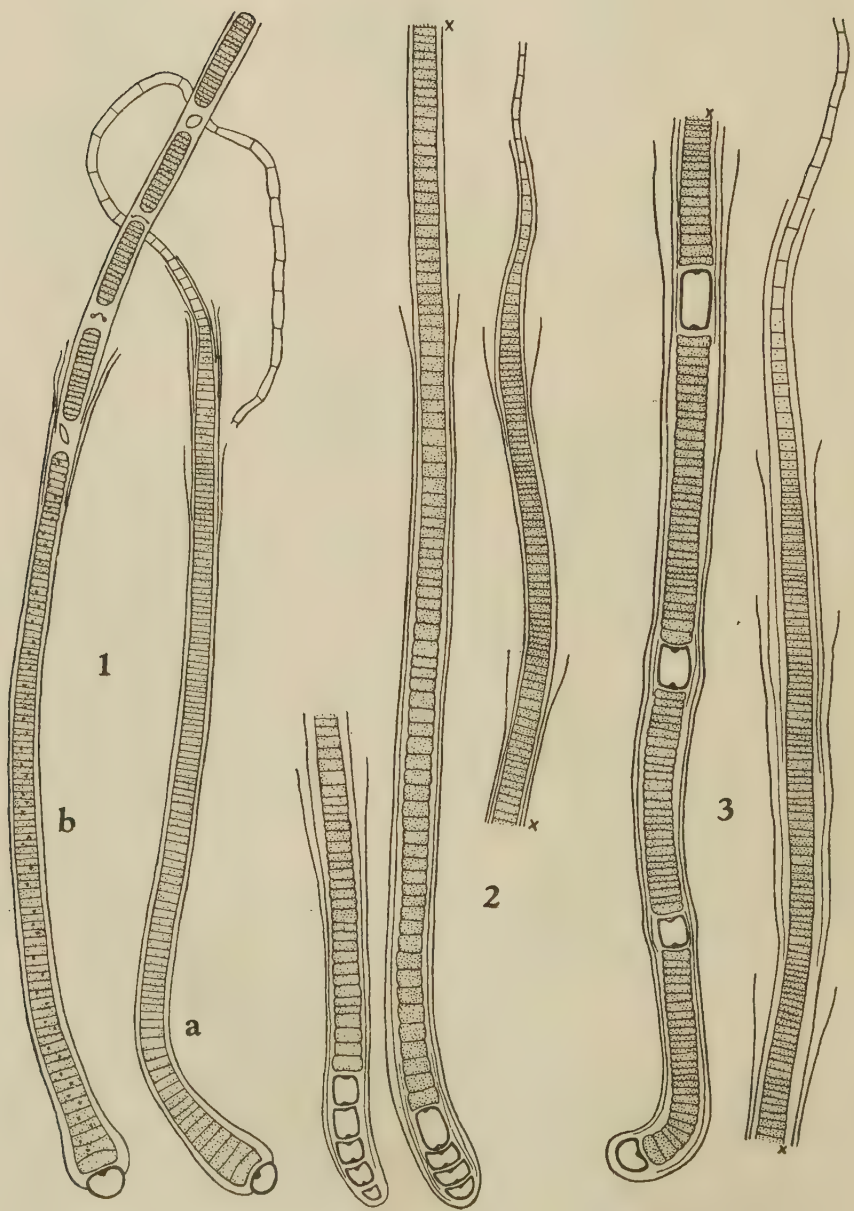


PLATE II

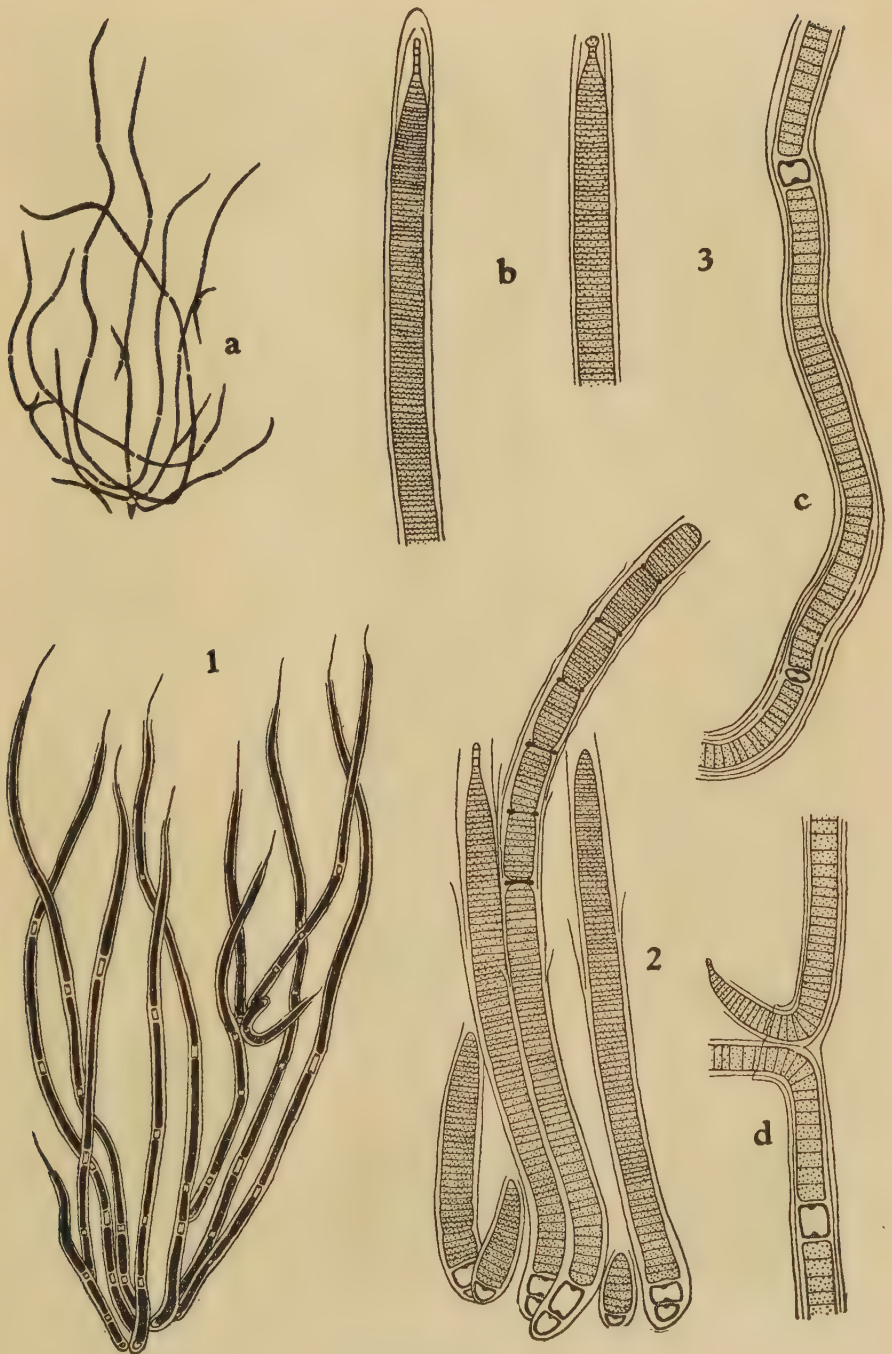


PLATE III

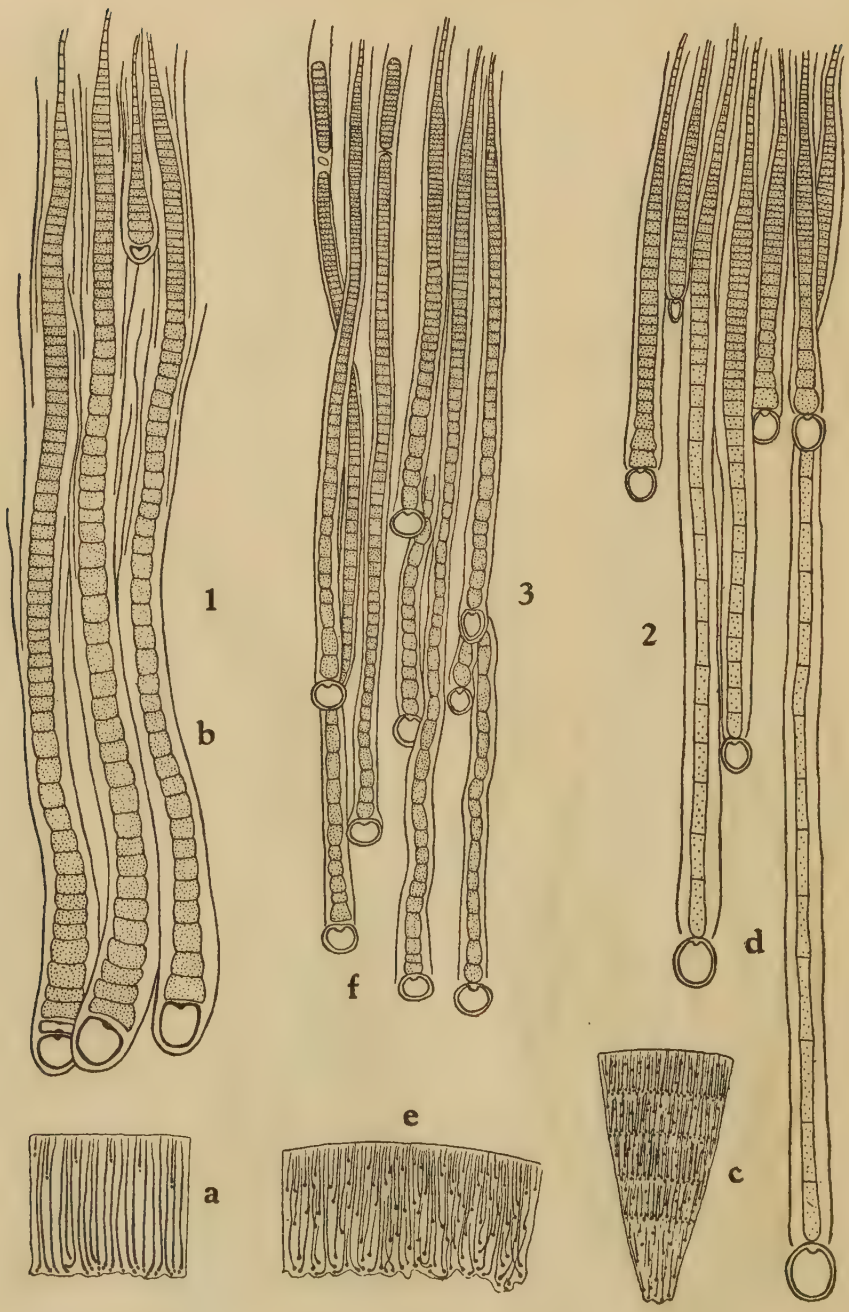


PLATE IV

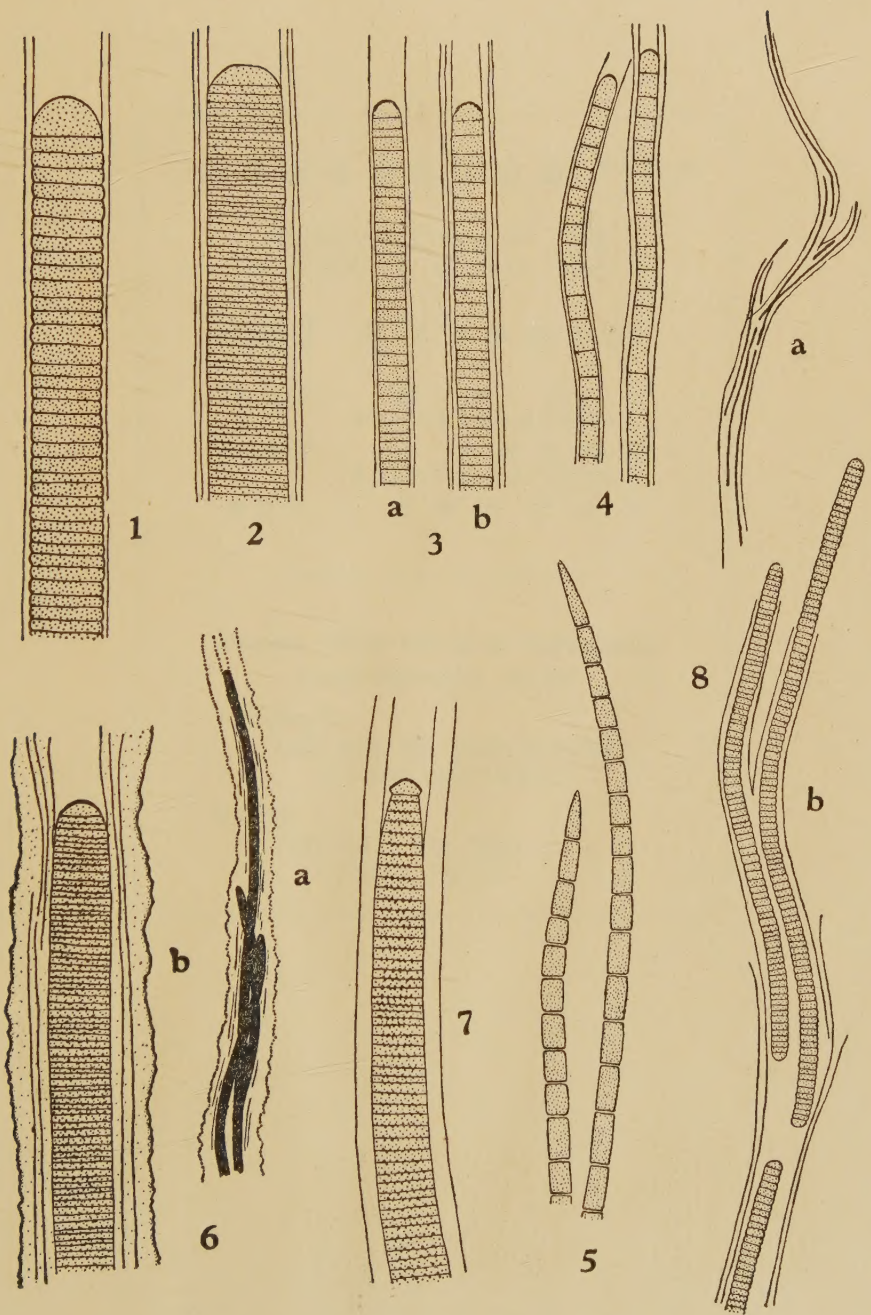


PLATE V

京都大学農学部紀要　第六十六號

昭和二十八年三月二十五日　印刷
昭和二十八年三月三十日　發行

編集兼發行者　京都大学農学部

印刷者　早速鎭夫
京都市下京區松原通高倉東入

印刷所　泉書店印刷部
東京都中央區日本橋二丁目6番地

發賣所　丸善株式會社

Memoirs of the College of Agriculture, Kyoto University No. 66

Published By
COLLEGE OF AGRICULTURE,
KYOTO UNIVERSITY

Sold By
MARUZEN CO., LTD.,
TOKYO, JAPAN

Memoirs of the College of Agriculture, Kyoto University

No. 1.	May	1926 (Entomological Series No. 1)
No. 2.	November	1926 (Chemical Series No. 1)
No. 3.	November	1927 (Phytopathological Series No. 1)
No. 4.	November	1927 (Chemical Series No. 2)
No. 5.	September	1928 (Chemical Series No. 3)
No. 6.	October	1928 (Chemical Series No. 4)
No. 7.	November	1928 (Phytopathological Series No. 2)
No. 8.	February	1930 (Chemical Series No. 5)
No. 9.	February	1930 (Chemical Series No. 6)
No. 10.	April	1930 (Entomological Series No. 2)
No. 11	February	1931 (Chemical Series No. 7)
No. 12.	February	1931 (Chemical Series No. 8)
No. 13.	February	1931 (Phytopathological Series No. 3)
No. 14.	February	1931 (Botanical Series No. 1)
No. 15.	November	1931 (Chemical Series No. 9)
No. 16.	November	1931 (Chemical Series No. 10)
No. 17.	December	1931 (Chemical Series No. 11)
No. 18.	January	1932 (Phytopathological Series No. 4)
No. 19.	March	1932 (Entomological Series No. 3)
No. 20.	April	1932 (Phytopathological Series No. 5)
No. 21.	April	1932 (Entomological Series No. 4)
No. 22.	May	1932 (Chemical Series No. 12)
No. 23.	August	1932 (Chemical Series No. 13)
No. 24.	December	1932 (Chemical Series No. 14)
No. 25.	March	1933 (Genetical Series No. 1)
No. 26.	March	1933 (Chemical Series No. 15)
No. 27.	June	1933 (Genetical Series No. 2)
No. 28.	June	1933 (Phytopathological Series No. 6)
No. 29.	January	1934 (Chemical Series No. 16)
No. 30.	January	1934 (Phytopathological Series No. 7)
No. 31.	March	1934 (Chemical Series No. 17)
No. 32.	July	1934 (Genetical Series No. 3)
No. 33.	November	1934 (Chemical Series No. 18)
No. 34.	March	1935 (Genetical Series No. 4)
No. 35.	September	1935 (Chemical Series No. 19)
No. 36.	October	1935 (Phytopathological Series No. 8)
No. 37.	February	1936 (Chemical Series No. 20)
No. 38.	September	1936 (Genetical Series No. 5)
No. 39.	April	1937 (Genetical Series No. 6)
No. 40.	April	1937 (Chemical Series No. 21)
No. 41.	May	1937 (Genetical Series No. 7)
No. 42.	March	1938 (Chemical Series No. 22)
No. 43.	March	1938 (Genetical Series No. 8)
No. 44.	May	1938 (Entomological Series No. 5)
No. 45.	October	1938 (Chemical Series No. 23)
No. 46.	March	1939 (Horticultural Series No. 1)
No. 47.	January	1940 (Phytopathological Series No. 9)
No. 48.	March	1941 (Entomological Series No. 6)
No. 49.	March	1941 (Entomological Series No. 7)
No. 50.	March	1941 (Genetical Series No. 9)
No. 51.	September	1941 (Entomological Series No. 8)
No. 52.	December	1942 (Genetical Series No. 10)
No. 53.	December	1942 (Entomological Series No. 9)
No. 54.	October	1943 (Entomological Series No. 10)
No. 55.	December	1943 (Genetical Series No. 11)
No. 56.	July	1944 (Horticultural Series No. 2)
No. 57.	July	1950 (Chemical Series No. 24)
No. 58.	September	1951 (Phytopathological Series No. 10)
No. 59.	March	1950 (Fisheries Series No. 1)
No. 60.	March	1950 (Chemical Series No. 25)
No. 61.	November	1951 (Phytopathological Series No. 11)
No. 62.	March	1952 (Fisheries Series No. 2)
No. 63.	March	1952 (Chemical Series No. 26)
No. 64.	January	1952 (Botanical Series No. 2)
No. 65.	December	1952 (Chemical Sereis No. 27)